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COPPER–NICKEL (70:30) ALLOY.

By MASON S. NOYES, MEMBER.*

One of the new developments undertaken by the Bureau of Engineering under the stimulus of the present naval shipbuilding program is the selection of "Copper-Nickel (70:30) Alloy" tubes for salt-water piping under this Bureau's cognizance. The present range of pipe sizes is from ¼-inch to 5-inch. Heretofore dependence has been placed upon copper tubing heavily coated on the interior with soft solder.

The name "Copper-Nickel (70:30) Alloy" is used to designate an artificial combination of about 70 per cent copper and 30 per cent nickel plus up to 1 per cent of tin or zinc and smaller amounts of other metals. These proportions of copper and nickel are almost exactly the opposite of those for the natural alloy "Monel" and so this combination is often described as a "reverse Monel."

* Design Division, Bureau of Engineering.

It is found on the market under such trade names as "Super-Nickel" and "Adnic." Further, the trade name "Ambrac" designates the alloy when it has been modified by increasing the zinc to 5 per cent at the expense of copper.

The alloy weighs about 555 pounds per cubic foot, has a coefficient of thermal expansion of 0.0000091 per degree F. and a modulus of elasticity of 21,300,000 pounds per square inch. Its resistivity is about 250 ohms per circular mil per foot at room temperature and its plastic range as shown on Figure 1, from 1170 degrees C. (2140 degrees F.) at the solidus line to 1220 degrees C. (2230 degrees F.) at the liquidus line, is only 50 degrees C or 90 degrees F.

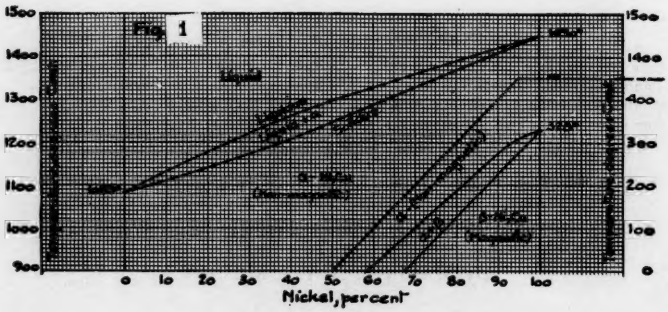


FIG. 1.—SHORTENED NI:CU EQUILIBRIUM DIAGRAM.
(From International Critical Tables, Vol. II.)

The physical requirements specified for pipe-size tubes ¼-inch to 5-inch are: ultimate tensile strength 60,000 pounds per square inch, yield point 45,000 pounds per square inch, and elongation in 2 inches 15 per cent. (No similar definite physical requirements have been set for condenser tubes because the chemical properties are made wide enough to include both 80:20 and 70:30 alloys whether with or without the 5 per cent zinc in place of copper.) Table I gives the results of tests at the Naval Engineering Experiment Station on two sets of tubing 0.065-inch thick made of 70:30 alloy. Figure 2 is a composite diagram of the results reported by C. L. Clark and A. E. White* for ¾-inch bars given a ⅛-inch

* C. L. Clark and A. E. White, Transactions A. S. M. E., 1931, FSP-53-15.

final cold draw, and two additional curves, in dot and dash lines on Figure 2, show the effect of annealing on the strength of the "Ambracs," as given by W. H. Bassett.* Figure 3 is a comparison made by W. B. Price† from U. S. Bureau of Standards tests of 70:30

TABLE I.

Pipe Size	*Outside Diameter (Inches)*	*Ultimate Tensile Strength As Received*	*Silver-Soldered*	*Finish of Tubing*	*Ultimate Load Tube*	*Joint**
¼	0.540	62400	61900	Full	6050	6100
¾	1.050	67000	62000	Full	13500	11800
1¼	1.660	67800	58000	Full	22100	20675
¼	0.540	85800	51000	Polished	8325	.....
¾	1.050	85100	51600	Polished	17150	12800
1¼	1.660	83000	52600	Polished	27050	.....

* Average of 3, using tin-lead (50-50) solder and standard solder coupling.

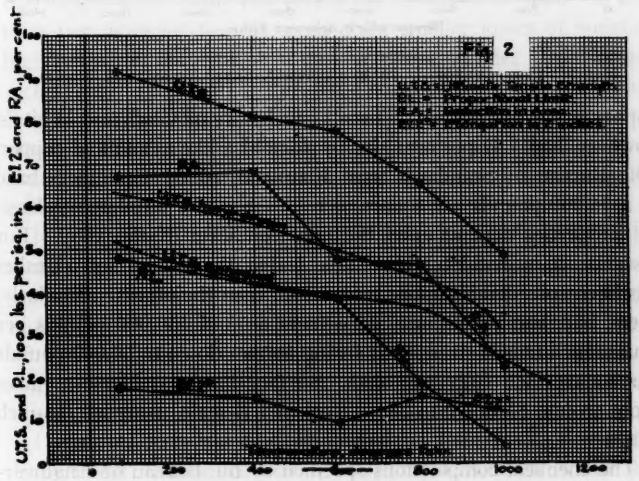


FIG. 2.—SHORT-TIME TESTS OF ¾-INCH BARS.

* Written discussion, p. 355, Symposium on Effect of Temperature on Properties of Metals, 1931.

† W. B. Price, Mining and Metallurgy, Nov., 1927, p. 474.

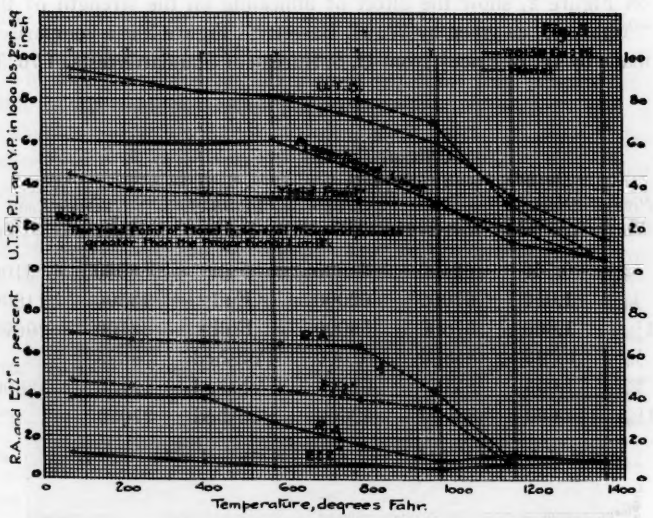


FIG. 3.—COMPARISON OF 70:30 COPPER-NICKEL ALLOY AND MONEL.

copper-nickel and Monel. These ¾-inch bars of Clark and White's, however, had 5.67 per cent zinc in place of a like amount of copper. The Bureau of Standards used Flatmetal, rolled 4 numbers hard to a 94,000 pounds per square inch U.T.S. The ultimate mechanical properties depend upon the final condition of the alloy. For instance, it is evident from Table I that the second set of tubes has been considerably more cold-drawn than the others. Similarly, sheet, bar, and wire stocks vary from around 130,000 pounds per square inch tensile strength at spring temper down to 50,000 pounds per square inch fully annealed. Surface hardness likewise varies from around 85 down to 35. (Rockwell B-scale, using a 1/16-inch ball.)

The chemical compositions specified by the Bureau of Engineering for pipe-size tubing and also favored for castings are:

Element	*Cu.*	*Ni.*	*Sn.*	*Mn.*	*Zn.*
Tubing	Balance	29 min.	1.20	1.00	1.00
Castings	Balance	29 to 30	1.25	0.50	trace

Element	*Fe.*	*Pb.*	*Si.*	*C.*	*Al.*	*Other Elements*
Tubing	0.50	0.05	0.10	.....	.....	0.50 max.
Castings	0.50	nil	0.50	0.10	trace	.....

Tubing rather than pipe has been specified in order that it may be used with the Navy's soldered fittings,* in sizes 2-inch and under, the joints being made up with tin-lead (50:50) solder. Sea-water piping is the only service where the copper-nickel tubing is specified and forms one of the two services in which the " soft " tin-lead solder is allowable. For sizes from 2½-inch to 5-inch the tubing is to be made up with the Bureau's new silver-soldered composition flanges, the fittings being the usual standard composition flanged design.

It is evident from the data presented in Figures 2 and 3 that this copper-nickel alloy has very good resistance to heat. In addition, just as nickel-bearing steels show smaller losses of weight at high temperatures than plain carbon steels, so does 70:30 copper-nickel resist oxidation better than copper under like conditions. It is also evident that since specifications set mechanical properties which in effect are suitable for a low-carbon steel, the alloy can be machined and otherwise worked very much as if it were a low-carbon steel.

It is proposed in this article to detail why from among all the metals and alloys possessing reasonable corrosion resistance to sea-water conditions the Bureau of Engineering chose copper-nickel (70:30) alloy, then to describe briefly the reports on several of the installations in service, and finally to conclude with some suggestions on preparing it for naval service from the rolled or drawn form.

Corrosion tests as now conducted at the Naval Engineering Experiment Station consist of (*a*) rapid rotation while semi-submerged in brackish water, (*b*) slow movement through a circular path in an electrolytic cell containing brackish water, and (*c*) close

* See JOURNAL A. S. N. E., Feb., 1935, p. 57.

exposure to an impinging jet of brackish water carrying entrained air. The first report on these recent tests contained comparative data on three different combinations of copper and nickel: 85:15, 80:20 and 70:30. In addition, Monel, Admiralty, and the modified 80:20 of Figure 2 (*i.e.*, 75:20:5 Cu-Ni-Zn) were tried. Specimens in the form of 2-inch tubing were presented for all the alloys and metals tested.

The vertical rotating test (*a*) exposed these tubing specimens to three (3) different corrosive situations illustrative of actual service conditions: moist salty air about the above-water portion, repeated wetting and drying at the waterline due to the turbulent surface of the water, and rapid flow around the underwater portion. The surface speeds employed and the duration of each test were as follows:

Admiralty,	85:15, 75:20:5	10 feet per second	45 days
18:8,	85:15, 75:20:5	10 feet per second	121 days
.....	85:15, 75:20:5	20 feet per second	65 days
Admiralty,	Monel, 70:30	20 feet per second	41 days
			(Admiralty 21 days)

All the copper-nickel alloys had bands of green corrosion products and brown film just above the waterline and a film of light brown over the entire underwater portion. The surface of the 85:15 and 75:20:5 were definitely roughened. The Monel was smooth, but discolored. The end of the Admiralty tube was slightly roughened. The 70:30 was smoothest and undoubtedly had the least amount of corrosion.

The electrolytic cell test (*b*), conducted at a very low surface velocity, increases the corrosion rate of electrically connected metals and alloys by providing two depolarizing influences: slow movement of the specimens through the corroding liquid and continual renewal of the supply of dissolved or entrained oxygen to combine with the liberated hydrogen, by supplying a steady flow of fresh corroding liquid through the cell. Copper, red brass, and 85:15 copper-nickel proved to be anodic to cast composition "G." Additional tests completed too late to be tabulated in the report, showed 70:30 copper-nickel alloy to reveal similar characteristics with compositions "G" and "M" (Figure 4). The 85:15 lost 0.1382

grams in weight while the composition "G" was losing 0.0758 grams. This difference in weight loss was only about one-half the value observed for red brass and composition "G." The report adds: "It appears that composition 'G' would be a satisfactory material for valves and fittings in conjunction with copper-nickel pipe. Moreover, since the pipe material is anodic to the material of the valves and fittings and since the mass of the former in all probability will be much greater than the latter, it appears that a good balance would be obtained with this combination."

Fig. 4

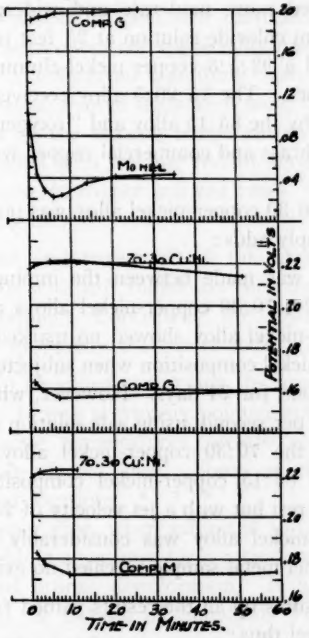


FIG. 4.—ELECTROLYTIC CELL TESTS.

Impingement resistance tests (*c*) were made with salty river water and with aqueous sodium chloride solution. The former contained a considerable amount of solids and the change was made to eliminate any erosive effect of these solids. Of these tests the report says:

"Definite classification of the alloys with regard to resistance to impingement attack is difficult. The depth of pitting and the extent of the area from which film is removed are the only means of evaluating the results. These factors depend upon the type of material and the condition of impingement at the surface of the specimen."

In salty river water at 29 feet per second velocity the 18:8 steel and a "tinned" copper showed maximum resistance. Admiralty, the 75:20:5 alloy, and the 85:15 alloy revealed maximum damage with a tendency to pit opposite the jet, whereas the red brass and the copper suffered more moderate and widespread injury. In the aqueous sodium chloride solution at 25 feet per second velocity the 18:8 steel and a 92:5:3 copper-nickel-aluminum alloy showed maximum resistance. The 75:20:5 alloy received the most severe damage, followed by the 85:15 alloy and "oxygen free" (HCOF) copper. The red brass and commercial copper were as in the salty river water tests.

Strip or sheet 70:30 copper-nickel alloy was not available at first and the report simply adds:

"A comparison was made between the impingement resistance of the 85:15, 80:20, 70:30 copper-nickel alloys and Monel metal. The 70:30 copper-nickel alloy showed no marked superiority over the 85:15 copper-nickel composition when subjected to a jet velocity of 25 feet per second for 24 days. However, when tested at a jet velocity of 14 feet per second, using salt solution containing 20,000 ppm of chlorine, the 70:30 copper-nickel alloy showed definite superiority to the 85:15 copper-nickel composition. Under the same conditions of test but with a jet velocity of 25 feet per second, the 80:20 copper-nickel alloy was considerably attacked after 4 days, whereas Monel metal sample revealed no evidence of attack."

The test report sums up all the results gained from all the alloys of copper and nickel thus:

"Results of tests up to the present time indicate that Monel metal is comparable with the 70:30 copper-nickel alloy and should give good service under conditions of salt water corrosion when fittings of like composition are used.

"In general, the copper-nickel alloys have shown greater resistance to the several types of corrosion attack than copper, red brass, silicon-manganese bronze or Admiralty metal. The 75:20:5 copper-nickel-zinc alloy appears to offer no advantage over the 70:30 copper-nickel composition. However, the former alloy has shown up fully as well as the 80:20 and 85:15 copper-nickel alloys."

As a test of weld metal rings of sheet material were welded or brazed to the tubing specimens of the same metal which had already been tested in the vertical rotating test (*a*). The results were described in part thus:

"The corrosion attack for specimens subjected to either brazing or welding temperatures was not appreciably more severe than for pipes tested in the as-received condition, with the exception of copper. This material showed noticeably more corrosion attack in the areas affected by the brazing temperatures. All of the pipe materials were welded with welding rod of similar composition to the pipe material, except copper and red brass. These alloys were brazed with brazing alloy."

As stated in the first paragraph of this article, copper tubing coated on the inside with soft solder has been the standard practice for salt water piping. Concerning the results of tests with "tinned" copper specimens, the report states:

"A word should be added concerning the use of copper for salt water pipe lines. It was previously pointed out that copper pipes subjected to brazing temperatures revealed enhanced corrosion attack in the heat-affected area. Some of the service failures occurred in similar locations * * *

"'Tinned' copper pipe, when subjected to salt water corrosion in the rotating spindle apparatus for a considerable period of time, reveals a streaked bronze discoloration. It has been shown by P. D. Merica (U. S. Bureau of Standards Tech. Paper No. 90, 1917) that the copper and tin combine to form a bronze and that the external tin-rich layer is anodic toward copper but the intermediate layer of tin-copper alloy is cathodic toward copper. When the copper surface is exposed corrosion proceeds rapidly. Moreover, coatings of tin as ordinarily applied by the hot-dipping process are likely to contain minute perforations. Hence, it does not

appear that tin coatings offer any particular promise for prolonging the life of copper pipe under conditions of salt water corrosion."

In summing up, the Naval Engineering Experiment Station suggests:

"Should the Bureau consider a considerable departure from the previous practice with regard to salt water pipe material, it is recommended that copper-nickel alloy of approximately the 70:30 composition be considered for salt-water pipe lines.

"Should the Bureau not desire to go so far as to require valves and fittings of similar composition to the pipe material referred to, it is further recommended that valves and fittings of composition 'M' or 'G' be used."

Similar data reported in England and numerous satisfactory performances of 70:30 copper-nickel alloy tubing in various marine condenser installations are cited later in this article. On the basis of all these data, the Bureau of Engineering proceeded to introduce 70:30 copper-nickel alloy tubing for salt water piping. Wishing to use the Navy soldered fittings (of composition "M") for all non-ferrous piping and to take advantage of their dual-solder feature, it was decided to provide stream-line joints bonded by tin-lead (50:50) solder. However, lest this choice should lead to accelerated corrosion due to the combination of copper-nickel tubing, tin-lead solder, and copper-tin-zinc-lead fittings, corrosion tests were made on a variety of joints using either tin-lead (50:50) solder or one of several silver solders. The tensile strengths of these joints also were determined and Table I contains the average values. In the course of these strength tests the writer found that soft solder joints would be made up and broken three times before the maximum strength of the joint was developed.

The corrosion tests of the various joints were carried out by slitting the joints in two and submerging them in the electrolytic cell for 40 days at a surface velocity of about 39 feet per minute. Careful scrutiny of the specimens showed no marked corrosion attack caused by a combination of copper-nickel tube, composition "M" or "G" fitting, and either tin-lead or silver solder, in salt water. There was a *slight* pitting between the naval bronzes and the solder, and apparently somewhat more noticeable for composition "G" than for composition "M."

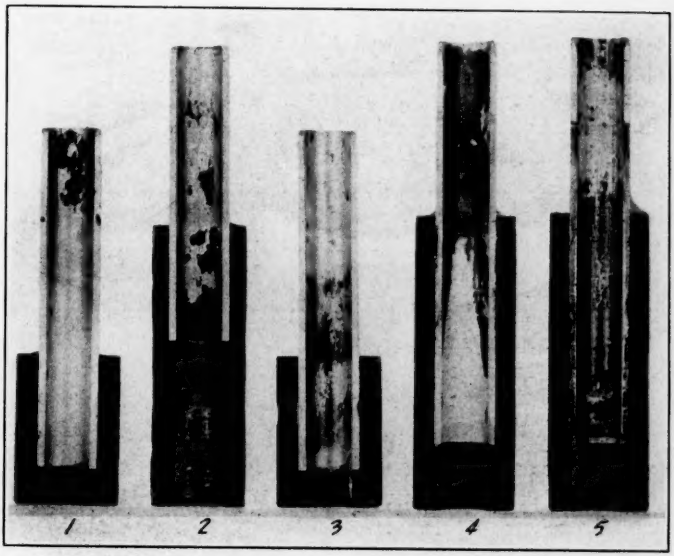


PLATE I.

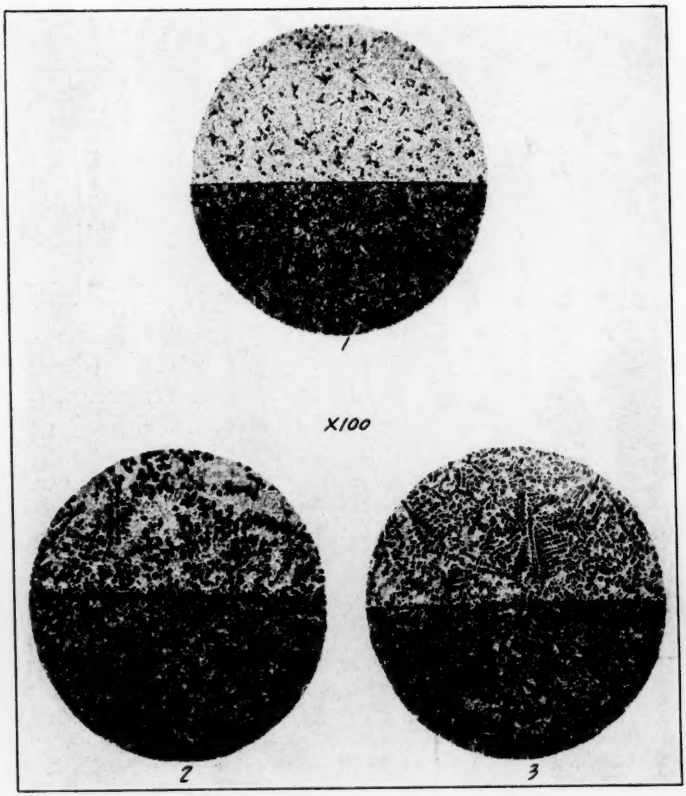


PLATE II.

Splitting these test joints longitudinally exposes large areas of all three alloys to corrosion attack. In the original joints, the only point where the corrosive medium comes in contact with all three alloys practically simultaneously is at the shoulder or bottom of the recess in the fitting where the end of the tubing butts up against the casting. Here a narrow ring of solder is exposed, but no corrosive effects are visible. Plate I shows 70:30 copper-nickel alloy tubing soldered to cast bronze couplings. Joints 1 and 2 have tin-lead (50:50) solder and compositions "G" and "M," respectively. Joints 3 and 4 have a low melting point silver solder, developed especially for nickel alloys, and compositions "G" and "M," respectively. Joint 5 is a duplicate of Joint 4.

The tin-lead (50:50) solder complied with the Navy Department Specification 46S14. The three silver solders complied with the following chemical requirements:

Type	*N. D. Specs.*	*Silver*	*Copper*	*Zinc*	*Phosphorus*	*Cadmium*	*Plastic Range*
High	47S13, Gr. I	45	30	25	....	....	.....
Medium	47S13, Gr. III	15	80	.....	5	....	1200 to 1300° F.
Low	M-221 (tentative)	50	15.5	16.5	....	18	1120 to 1170° F.

Photomicrographs were taken of the split test joints at a point on the surface of the tubing and are shown on Plate II. Photos 1, 2 and 3 show the bond between tubing and the "low" type, "medium" type, and "high" type of silver solder, respectively. This designation refers to their respective melting points. In each photo there appears to be a band of the silver-rich alloy bordering the surface of the tubing, most noticeably in Photo 2 of the "medium" type silver solder. The upper portion of each photo is the solder and the lower portion the tubing. An acid ferric chloride solution was used for etching.

Therefore, if for any reason whatsoever service conditions should prove the tin-lead solder unsuitable (as has been intimated by some), the Bureau is in a position to substitute any one of the above three silver solders without making any other changes in the piping installation. The tubing specifications consequently provide for a tubing adapted to soldered fittings and flanges.

The International Nickel Company completed last spring exposure tests of 61, 97, 101 and 140 days duration on various nickel-

bearing alloys. Sheet specimens were suspended totally submerged from floats at three different locations along the mid-Atlantic coast. In the course of laboratory work paralleling this test, they reported that corrosion of 70:30 copper-nickel alloy was accelerated in salt water through electrical connection with the following metals only: nickel, Monel, and stainless steel of the 18:8 type. When the exposed specimens were removed for examination, they were measured and rated on the basis of loss in weight, pitting on the surface, concentrated electrolytic cell effects at the specimen supports, corrosion attack at the sheared edges, and fouling.

At Barnegat Bay the 70:30 copper-nickel alloy was found lowest in all five types of corrosion. At the Kill van Kull (Staten Island, N. Y., Harbor) the 70:30 alloy was second to Monel and nickel in minimum weight loss and to "Silveroid" (55:44:1 copper-nickel-iron) in minimum cell effects at the supports. It stood lowest in the other three. At the Aquarium (Battery Park, N. Y. C.) the 70:30 alloy was tied with its companion 70:29:1 copper-nickel-tin alloy in minimum weight loss and second to copper in minimum cell effects at the supports. It is understood that a complete report on these findings is to be prepared by the International Nickel Company. The Aquarium portion of this exposure test was of somewhat of a laboratory nature as the specimens were placed in the tanks containing sea water. This is brought in regularly from the ocean to freshen the Aquarium tanks. Where the rotating spindle test and the usual condenser tube test subject the samples to water moving at fairly high velocity, this test provided nearly quiescent water.

A similar set of conditions is found in the final report, to the Institute of Metals, on the Relative Corrodibilities of Ferrous and Non-ferrous Metals and Alloys.* It is entitled: The Results of Three Years' Exposure at Southampton Docks. Its synopsis is quoted *verbatim:*

"Nearly one hundred bars of ferrous and non-ferrous metals were exposed to sea action at Southampton Docks for three years, and an account is given of seventy-two of these. The metals examined included lead, zinc, tin, aluminum, copper, nickel, and

* Part III, J. Newton Friend, Journal of the Institute of Metals, Vol. XLVIII, 1932, p. 109; also Part I, J. Newton Friend, Journal of the Institute of Metals, Vol XXXIX, p. 111.

various alloys containing iron, chromium, nickel, copper, and zinc. The effect of grain-size on the corrodibility of brass has been studied. The results appear to indicate that small grain is preferable to coarse. Nickel-copper alloys, particularly the 70:28 alloy, offered great resistance to corrosion. High-grade zinc and tin were slightly more attacked than the less pure metals. The effect of arsenic in copper is discussed. Tension, riveting, and cold-working did not appreciably affect the corrosion of nickel-chromium alloy steels, but in every case cracks appeared at welds. Shell fauna did not appear to affect the corrosion of the metals appreciably while living. *Dead shelly fauna stimulated localized corrosion in alloy steels, nickel, and nickel alloys not rich in copper.** The alloy steels resisted corrosion well, but previous results showing that alloy steels are subject to serious localized corrosion are confirmed."

The test bars, 1⅛ inches in diameter by 2 feet long, were placed in oak frames which were fixed under a jetty at about half-tide level. On dismantling the frames, it was found that corrosion had not proceeded so far as expected. The oil from the ships aided in forming a partially protecting layer of mud around the bars which was not scoured off by the slowly moving water.

The copper-nickel alloys were represented by 100 per cent nickel, 70:28 nickel-copper ("Corronil"), 55:44:1 ("Silveroid"), 80:20, 90:10, 98:2, and 100 per cent copper (with and without arsenic). In order of total weight loss they began with none for "Corronil," closely followed by "Silveroid" and nickel, then by 80:20 and 90:10. The "Corronil," "Silveroid" and nickel (slight), however, showed traces of shell fauna attack. The 80:20 and 90:10 alloys were uniformly corroded, with a weight loss one-third and two-thirds that of the copper bars, respectively, and one-fortieth and one-twentieth that of 0.15 per cent copper steel and mild steel. On the basis of the weight losses given, a 70:30 copper-nickel alloy would have lost no more than one-half that of the 80:20 alloy.

Copper-nickel alloys are not new to marine work. Robert Worthington† has given two years ago a brief review of the prog-

* The italics are the writer's, not the report's.

† "10-Years' Progress in Copper-Nickel Condenser Tubes," Marine Engineering, July, 1933, p. 266.

ress made by these alloys during the preceding ten years in marine condensers. He states that the first commercial tubes were used in a power plant ashore in 1922 in England and were of 80:20 copper-nickel alloy, and further that the Canadian-Pacific steamships *Melita* and *Minnedosa* were retubed completely in 1926 with copper-nickel condenser tubing, the first ships to be fitted out 100 per cent. The brass tubes previously installed in these ships had an average life of one year. The 1926 copper-nickel tubes were still in the condensers in 1933 and had proved satisfactory. As a result the use of such tubing had been extended throughout nearly the entire Canadian Pacific Steamships, Ltd., fleet. The latest was the *Empress of Britain.* Other large ocean liners mentioned were the French *Champlain* and *l'Atlantique,* the Italian *Rex* and *Conte di Savoia,* and the United States Lines' *Manhattan* and *Washington.* It may be of interest to note that the condensers of the *Empress of Britain,* each of the inboard ones having 20,700 square feet and each of the outboard ones having 9600 square feet, are fitted with ¾-inch tubes of 70:30 alloy; that the four condensers of the *Conte di Savoia,* having 17,200 square feet each, also are tubed with 70:30 alloy 19 millimeters outside diameter, 16 millimeters inside diameter in the top rows and 17 millimeters inside diameter in the two lower sections; that the *Rex* required slightly more tubing than this ship; and that the *Manhattan* and *Washington* condensers, of 16,500 square feet size, have tubes ¾-inch by No. 16 B.W.G. of 65:30:5 copper-nickel-zinc (Ambrac 30) alloy.

Prof. G. Bauer* gave the following data in "The Machinery Installations of the *Bremen* and Its Predecessors" as to the use of copper-nickel tubing:

"Each of the four condensers contains 7850 tubes of 19/16 millimeters (.748 inch–.630 inch) or 19/15 millimeters (.748 inch–.591 inch) in diameter and three of the condensers are equipped with tubes of brass composition while the fourth has tubes made of copper-nickel alloy." * * * These condensers are stated to have 20,000 square feet of surface.

"On July 5, 1930, one year has passed since the commissioning of the *Bremen* after satisfactory completion of the trials. The

* Schiffbau, Oct. 1, 15, Nov. 1, 1930; also Notes—JOURNAL A. S. N. E., Nov., 1930, p. 679, Feb., 1931, p. 153.

builders of the ship can look back with satisfaction upon this trial period, because no faults of the propelling plant, which necessitated repairs or changes worth mentioning, have shown up during that time. * * *

"Out of the 23,500 condenser tubes of normal composition nine sprang a leak and had to be replaced, while only one or two were replaced in one of the condensers equipped with 7850 tubes of copper-nickel alloy (see above).

"The copper cooler pipes of the small oil coolers for the blowers, main circulating water pumps, and Diesel engines had to be replaced by pipes of copper-nickel alloy, due to signs of corrosion showing up in the first two of the above mentioned auxiliaries." * * *

In conclusion, a few notes on the fabrication of rolled or drawn 70:30 copper-nickel alloy may be of value and interest to those who have occasion to handle this material. No information on casting this composition can be included. Not only would much space be required but also in the light of the corrosion test results on the Navy's composition "G" and "M" as reported by the Naval Engineering Experiment Station and quoted above, there appears at present to be no valid reason for the use of castings of a higher grade metal than composition "M" in locations exposed to salt water.

The 70:30 copper-nickel can be welded by both oxy-acetylene and the metallic arc. Suitable special welding rods have been developed, bare for gas and coated for the arc. Perhaps the most satisfactory proprietary flux to use for gas-welding is made into paste form with boiling water and brushed liberally onto both parent metal and welding rod. The weld metal is very fluid, so that overhead arc welding cannot be done on it. A skillful gas welder versed in handling non-ferrous materials can make satisfactory strength welds overhead but it is not an easy job and should be avoided unless no other method is possible. For this reason arc welding is not recommended except as a shop operation where the job can be so arranged that the work can be turned in order to provide all downhand welding.

The tubing joints selected by the Bureau of Engineering call for tin-lead (50:50) solder in soldered tube fittings and silver solder

in soldered tube flanges. It is considered by the writer that silver-soldering should be used for joining copper-nickel alloy construction rather than welding or riveting.

A word of caution here seems advisable. The alloy absorbs and conducts heat more slowly than copper. For this reason preheating of the tubing or sheet takes more time and more gases and the material should be carefully watched during this operation. The first visible red appears at about 980 degrees F. (525 degrees C.). The same delay in preheating the fitting or abutting sheet is encountered when these are also made of the 70:30 alloy. When both members forming the joint reach a cherry red which is 1300 degrees F. (700 degrees C.) melting of the specified flux can be observed which is the signal that only a little more heating is required before the Grade III silver solder is to be applied. This solder is the " medium " type already mentioned and is favored due to its low melting point and its low silver content. Because of its phosphorus content the torch flame should be kept away from it lest the phosphorus be burned out and its melting point therefore be considerably raised. Finally due to the alloy's low thermal conductivity less after-heating is required to check too rapid cooling.

The 70:30 copper-nickel alloy, having physical properties more those of a mild steel than of copper, can be machined and threaded with nearly the same effort as for mild steel. Anyone used to forming soft or ductile metals will have no trouble with this alloy.

The tubing cannot be worked hot, which means that it cannot be bent hot nor flared out readily for the soldering, brazing, or welding of side outlets or similar connections, as is so commonly done with copper (or steel) tubing. Instead for such extra connections cast fittings should be used or a boss silver-soldered onto the tube. In order to meet the specified physical requirements the tubing is drawn with a slight temper, so that it can stand shipment without getting out of round or without being otherwise damaged. Therefore any tube that is to be bent should be first torch annealed to about 1300 to 1500 degrees F., next allowed to air cool or cooled in water, then packed tightly with sand or filled with rosin (according to local practice), and finally bent *cold*. By reannealing and cooling, any buckles which may appear in thin wall tubing may be hammered out cold.

For guidance in forming any of the copper-nickel series of alloys, Figure 5* which is a full equilibrium diagram with temperatures in Fahrenheit degrees plotted against the percentage of nickel content is reproduced to show the working ranges and stress relief anneal temperature advised by the manufacturers. It may be well to remind here that in forging or annealing or otherwise hot-working the 70:30 alloy full allowance should be made for its low thermal conductivity and the time for heating be lengthened accordingly.

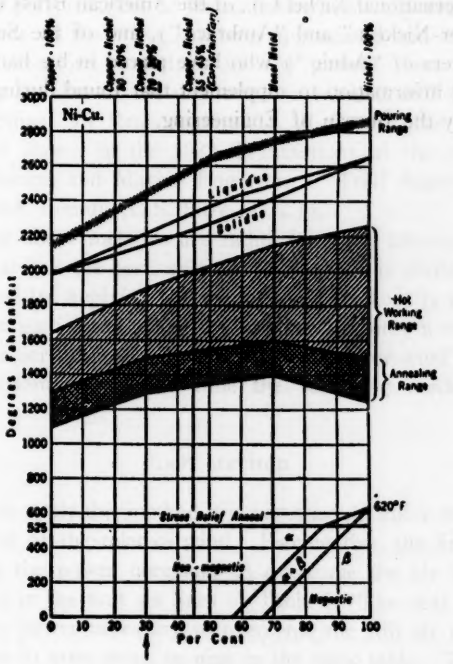


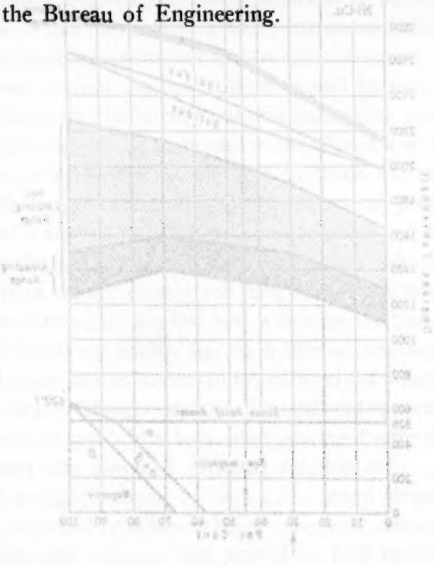
Fig.5

As revealed by the copper-nickel constitution diagram in Figure 5, these two metals form solid solutions of each in the other from room temperature right up to the melting point (solidus). There-

* G. F. Geiger, in "INCO," Vol. XII, No. 4, 1935, by courtesy of International Nickel Co.

fore the heating mentioned above only changes the grain size. There is no change in brittleness or corrosion resistance, nor can its structure be disturbed one way or another by normalizing, quenching, or slow-cooling. Annealing takes place at any temperature, which should be selected for the final strength or ductility desired. In fact, Figure 5 represents, except for the slight change in magnetic quality, a perfect example of the "ideal" or most simple form of constitution diagram for two metals.

The writer wishes to express his thanks to the representatives of the International Nickel Co., of the American Brass Co. (makers of "Super-Nickels" and "Ambracs"), and of the Scoville Mfg. Co. (makers of "Adnic") who have placed in his hands valuable additional information to supplement that found during the investigation by the Bureau of Engineering.



WIND RESISTANCE.

By E. A. Stevens, Jr., Member.

Although it has been known for a considerable time that wind affected the performances of ships, it has been only recently that the magnitude of the effect has been appreciated and steps taken to correct variations caused by it. At present there are three methods used. One of the methods is illustrated in "Speed and Power of Ships" by Rear Admiral D. W. Taylor, the other two methods are shown in the 1932 Transactions of the Society of Naval Architects and Marine Engineers ("Trial Analysis Methods" by Lieut. Comdr. A. S. Pitre (C.C.)).

All of the above methods are rather long and laborious and as the results are, at the best, only approximate, it is doubtful if the time required for applying any one of these methods is warranted, especially in such cases where the weather has only a very slight effect on the performance. In order to correct for wind resistance without spending too much time the following methods were devised:

FIRST METHOD.

In order to apply this method it is necessary to know the velocity and direction of the relative wind. Having this, the first step is to ascertain the power necessary to overcome the air resistance. This is done in the first six lines of Table I. The next step is to calculate the power necessary to overcome the still air resistance. This is done in lines seven to nine in the same table. The power necessary to overcome the increase (or to be credited for the decrease) resistance due to wind is the difference between line (6) and line (9).

TABLE I.

(1) v_a = Velocity of the relative wind in knots.

(2) Relative wind direction.

(3) $v\frac{3}{a}$

(4) C—Correction factor for relative wind direction from Figure 2. NOTE: If the wind is from forward the correction factor is plus, if from aft the correction factor is minus.

(5) $v\frac{3}{a} \times C$.

(6) $P_{aw} = .00001227 \times A \times v\frac{3}{a}$ = Horsepower required to overcome air resistance with wind.

(7) v_o = Speed of ship (over ground) on run.

(8) $v\frac{3}{o}$

(9) $P_a = .00001227 \times A \times v\frac{3}{o}$ = Power required to overcome air resistance with no wind.

(10) $P_w = P_{aw} - P_a$ = Power required to overcome increase resistance due to wind.

Having obtained the power necessary to overcome the increase resistance (or the power to be credited for decrease resistance) for each run on the measured mile, average these in the same manner as the shaft horsepower is averaged for the group of runs, *i.e.*, on a three-run group multiply the power required on the middle run by two, add to this the powers required on the other two runs and divide the sum by four. On a five-run group multiply the power required on the second, third and fourth run by two, add these together with the power required on the first and fifth run and divide the sum by eight.

AIR RESISTANCE.

The resistance offered by a plane placed at right angles to the wind is obtained from the following formula:

$$R_w = .004 \times A \times v\frac{2}{a}$$

and the power necessary to overcome this resistance is

$$P_w = .00001227 \times A \times v\frac{3}{a}$$

A = Area of plane in square feet.

v_a = Velocity of wind in knots.

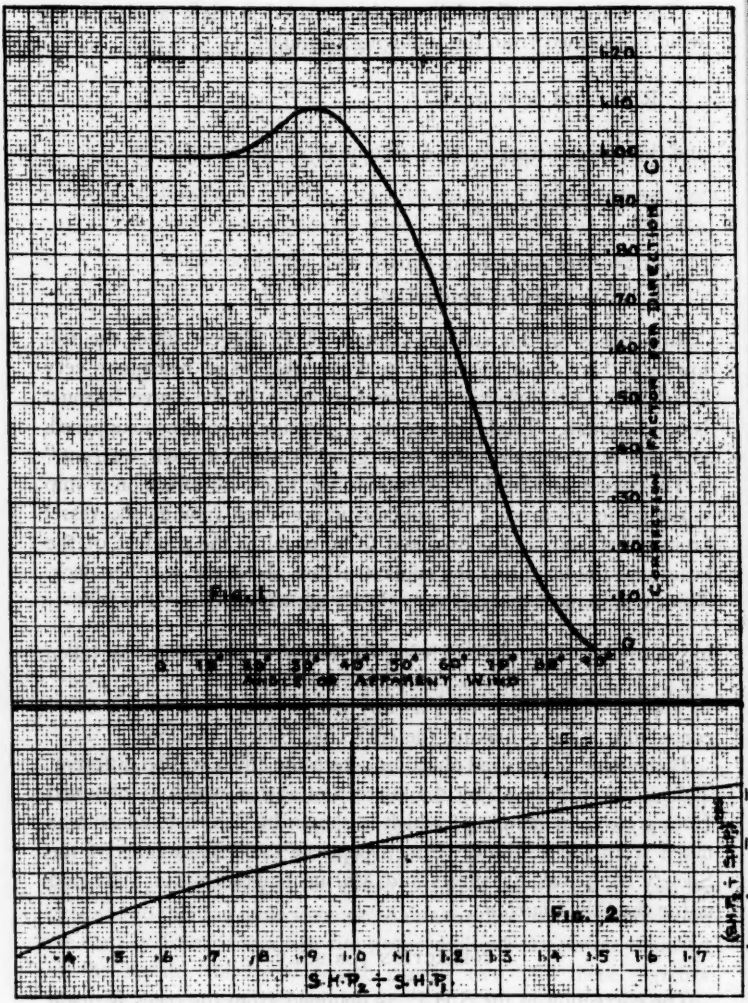
In a thesis on this subject Captain E. F. Eggert states the following: "It is not necessary to know this wind resistance very accurately. An approximation such as given by the above formula is good enough. Trial data are not so precise as has been supposed, and this approximate value is as good as the data will warrant."

The area taken in the calculations for the wind effect on a ship is the projected area of the superstructure when viewing the vessel from either end, and is assumed to be equal to the product of the beam and the height of the superstructure above the weather deck. This area, in most cases, is very closely approximated by the following formula: $A = \frac{B^2}{2}$; B being the beam. Care should be taken in approximating this area, as any excess will result in an overcorrection, thereby making the corrected S.H.P. too low.

If the wind is not dead ahead or astern the effect will be different. This is taken care of by the correction factor which is obtained from a curve, a sample of which is shown in Figure 1, which was taken from Lieut. Comdr. Pitre's paper in the Transactions of the Society of Naval Architects and Marine Engineers for 1932 and is for the S.S. *Clairton*.

CORRECTION FOR S.H.P.

The correction to the S.H.P. as obtained from the trials is made as follows:


1.20
1.10
1.00
C
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
Coefficient of Friction for Direction
0° 10° 20° 30° 40° 50° 60° 70° 80° 90°
Angle of Apparent Wind
Fig. 1
.4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7
S.H.P.₂ ÷ S.H.P.₁
Fig. 2

Let S.H.P. = Average S.H.P. for the group of runs obtained on the trial.

$S.H.P._2$ = Corrected S.H.P.

E.H.P. = Effective horsepower for the average speed for the group of runs.

P_w = Horsepower necessary to overcome increase resistance due to wind.

$$\text{Then } S.H.P._2 = S.H.P. \times \frac{E.H.P.}{E.H.P. + P_w}$$

The above formula is based on the propulsive coefficient being constant, which is very seldom the case, but whatever error there may be due to this, is less than those due to the inaccuracies in obtaining the velocity and direction of the wind.

CORRECTION FOR R.P.M.

If for any reason the shaft horsepower required for a given speed should increase or decrease the revolutions will increase or decrease directly as the .205 power of the S.H.P. The corrected R.P.M. can, therefore, be obtained as follows:

Let R.P.M. = Average R.P.M. for the group of runs obtained from the trial.

$R.P.M._2$ = Corrected R.P.M.

S.H.P. = Average S.H.P. for the group of runs obtained from the trial.

$S.H.P._2$ = Corrected S.H.P.

$$\text{Then } R.P.M._2 = R.P.M. \times \left(\frac{S.H.P._2}{S.H.P.}\right)^{.205}$$

The values of $\left(\frac{S.H.P._2}{S.H.P.}\right)^{.205}$ can be obtained from Figure 2.

ILLUSTRATION OF THE FIRST METHOD.

The S.S. *Clairton* will be taken to illustrate this method as very complete trial data on this ship have been published and the results can be compared with those obtained by other methods, this ship having been used by Admiral Taylor and Lieut. Comdr. Pitre.

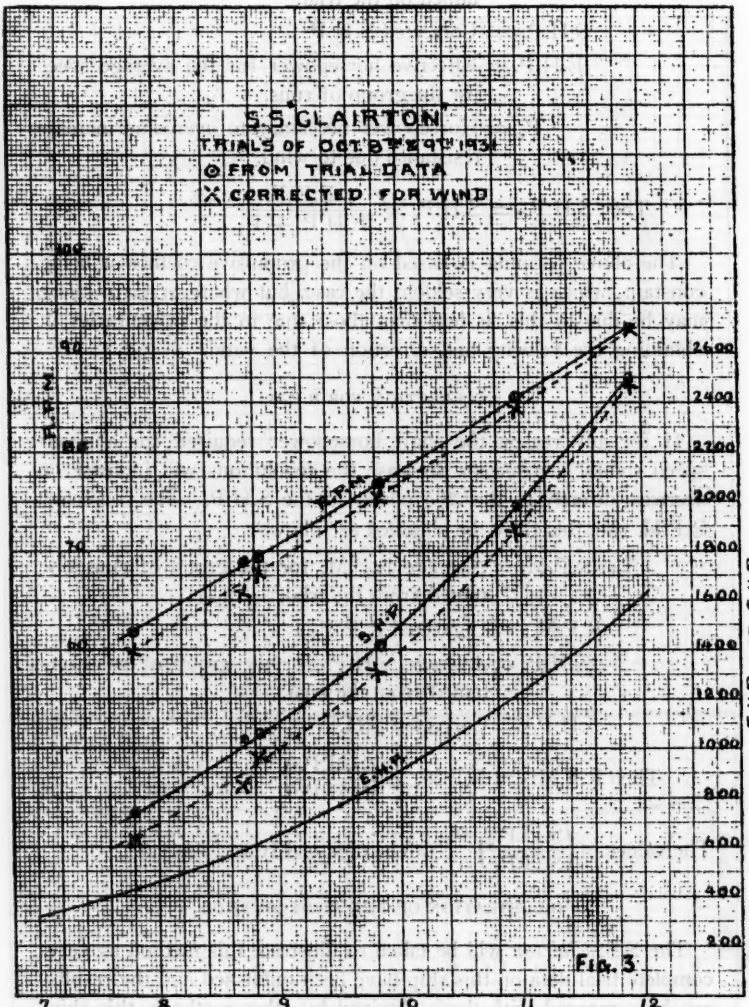

S.S. GLAIRTON
TRIALS OF OCT. 8TH & 9TH 1913
⊙ FROM TRIAL DATA
X CORRECTED FOR WIND
H.P. AND S.H.P.
KNOTS
7
8
9
10
11
12
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200

FIG. 3

The longitudinal projected area of this ship is very close to that given by the formula $A = \frac{B^2}{2}$ and this value has been used. As the beam = 55 feet A = 1513 square feet and the horsepower required to overcome air or wind resistance is as follows:

$$P_a \text{ or } P_w = .00001227 \times 1513 \times v \frac{3}{a} = .01855\ v \frac{3}{a}$$

The trial data is given in Table II.

Table III shows the use of Table I in obtaining the power required to overcome the increase resistance due to wind.

Table IV shows the calculation to obtain the shaft horsepower if there had been no wind during the trials.

Table V shows the calculation to obtain the revolutions per minute corrected for no wind.

The curves for the corrected shaft horsepower and revolutions per minute are shown by dotted lines in Figure 3, while the uncorrected curves are shown by full lines.

SECOND METHOD.

When no data have been taken for the speed and direction of the relative wind the corrections for wind effect can be made as will be explained below. This method is identical to the Taylor method except for obtaining the corrected shaft horsepower and differs from the one already explained in that the revolutions are used as a basis, the power and speed being corrected for the wind effect, while in the first method speed is used as the basis, the corrected shaft horsepower for no wind is obtained and the revolutions corrected for the difference between the actual and corrected powers.

In order to use this method, it is necessary that the runs be made progressively, that is, the slowest runs first, the next to slowest runs next, etc., the highest speed runs being made last or *vice versa*. Although it is desirable, if possible, to have all of the runs made on the same day, this is not necessary. However, it is advisable that at least three (better four) sets of runs be made on each day.

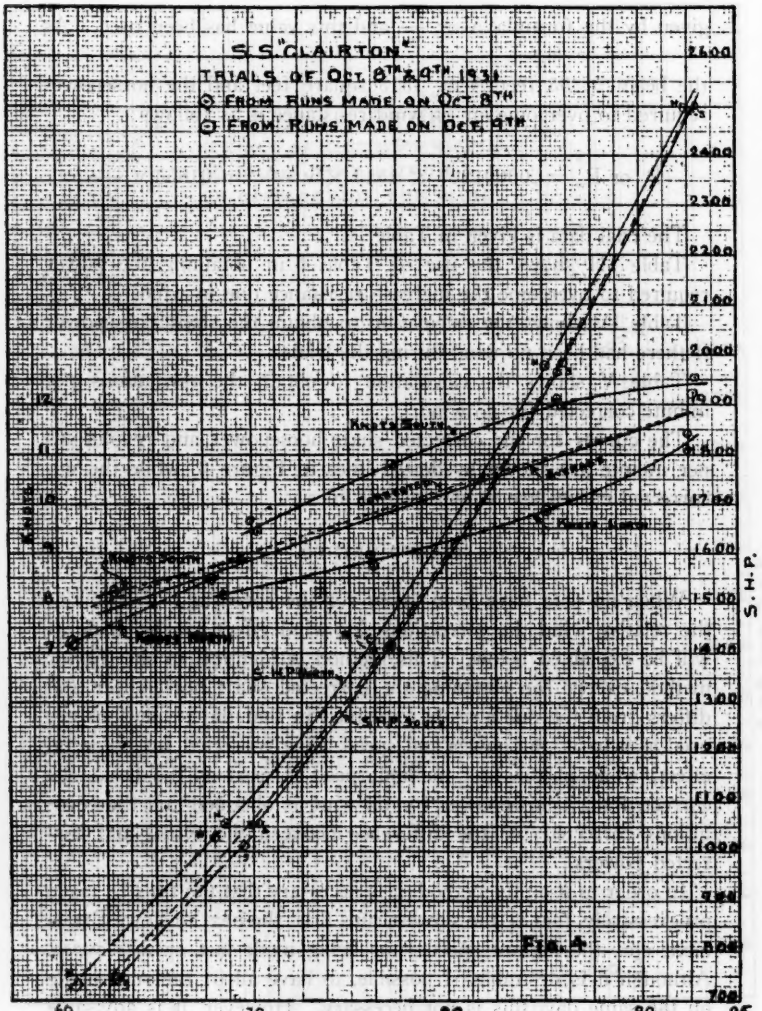

S.S. "CLAIRTON"
TRIALS OF OCT. 8TH & 9TH 1931
FROM RUNS MADE ON OCT. 8TH
FROM RUNS MADE ON OCT. 9TH
Knots Speed
Knots Speed
Knots Speed
Knots Speed
S. H.P. Curve
S. H.P. Curve
S. H.P.
R.P.M.
40
70
80
90
95
2600
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700

FIG. 4

The procedure is as follows: Plot (as shown on Figure 4) the speed and power for each run (from Table II), draw two power curves, one through the spots for the northbound runs, the other for the south. The same being done for speed.

It should be noticed that runs made on October 8th have been treated entirely separately from those made on the following day. While it is possible, in this case, to fair in the power curves for the individual runs made on both days, it would not be possible to do so for the speed curves. In some cases, however, it would be impossible to fair either the power or speed curves for the individual runs.

Enter in a table as shown in Table VI, R.P.M. (in Column I), power and speed for the north and south bound runs (S.H.P.$_n$ - Column II, S.H.P.$_s$ Column III, v_n Column VII and v_s Column VIII). These values are taken from Figure 4 for the revolutions stated in Column I.

Subtract the lesser shaft horsepower from the greater (in this case S.H.P.$_n$ — S.H.P.$_s$) and enter the result in Column IV. The values in Column V are one-quarter those in Column IV. Column VI is the sum of Column V and the lower values for S.H.P. (in this case it is Column III S.H.P.$_s$) and is the corrected shaft horsepower (S.H.P.$_2$) for the stated revolution when there is no wind. (This curve is shown on Figure 4 by the dotted line). Column IX is the mean of Columns VII and VIII (v_n and v_s) and is the average speed for the stated revolutions under conditions existing on the trial.

The correction for speed is the same as that used by Admiral Taylor and is shown in Table VII which is as follows:

Column I = R.P.M. taken same as Column I, Table VI.

Column II—v_1 = Average speed on trial for revolution stated in Column II from Column IX of Table VI.

Column III—S.H.P.$_d$ = Corrected shaft horsepower (for no wind) taken from Column VI of Table VI.

Column IV—S.H.P.$_n$ = Shaft horsepower from curve for northbound runs on Figure 4 (Column II of Table VI).

Column V—S.H.P.$_s$ = Shaft horsepower from curve for southbound runs on Figure 4 (Column III, of Table VI).

Columns VI and VII are obtained by the equations shown on this table (Table VII).

Column VIII—Speed correction factor for northbound runs and is equal to Column II — Column VI.

Column IX—Speed correction factor for southbound runs and is equal to Column II — Column VII.

Column X—v_n = Speed from curve for northbound runs on Figure 4 (Column VII of Table VI).

Column XI—v_s = Speed from curve for southbound runs of Figure 4 (Column VIII of Table VI).

Column XII—Corrected speed for northbound runs = Column X + Column VIII.

Column XIII—Corrected speed for southbound runs = Column XI + Column IX.

Column XIV—Corrected speed through water = average of Columns XII and XIII.

Although it is impossible, in some cases, as already shown, to fair in the speed and/or power curves for the individual runs. when all of the runs have not been made on one day, the average speed and power curves and the curves for the corrected average speed and power should fair in if the data is correct.

COMPARISON OF VARIOUS METHODS.

Comparisons of the corrected powers and revolutions obtained by these methods with those derived by other methods are shown in Tables VI and VII. In this connection it should be noted that the speed noted in Table II for the second group of runs made on October 8th is obviously incorrect, which is not surprising as only two, in place of three, runs were made at this speed. If this group had been neglected, as should have been done when drawing the power curve (corrected shaft horsepower by the first method), the corrected shaft horsepower for nine knots would have been 1020 in place of 1000.

The data for Tables VI and VII for the Taylor method were obtained from "Speed and Power of Ships," by Rear Admiral D. W. Taylor, while those for Captain Eggert and Mr. Schoenherr methods are from Vol. 40 of the Transactions of the Society of Naval Architects and Marine Engineers (1932).

TABLE II.

Data Taken from trials of S.S. *Clairton.*

Runs made on October 8, 1931.

Run No.	*Observed Speed*	*S.H.P.*	*R.P.M.*	*Relative Wind* — *Velocity in Knots*	*Relative Wind* — *Direction (Degrees)*
1 N.	7.25	738	60.76	26.1	F-40-P
2 S.	8.21	742	62.91	20.9	A-55-S
3 N.	7.52	733	60.70	24.7	F-35-P
Average	7.80	739	61.82	.....	.....
4 S.	8.88	1012	69.47	13	A-70-S
5 N.	8.54	1029	67.98	24.5	F-30-P
Average	8.71	1036	68.72	.....	.....

Runs made on October 9, 1931.

Run No.	*Observed Speed*	*S.H.P.*	*R.P.M.*	*Relative Wind* — *Velocity in Knots*	*Relative Wind* — *Direction (Degrees)*
1 S.	9.43	1059	70.24	12.2	A-40-P
2 N.	8.13	1059	68.51	24	F-25-S
3 S.	9.62	1053	69.96	8.6	A-40-P
Average	8.83	1058	69.31	.....	.....
4 N.	8.97	1430	76.13	23.2	F-15-P
5 S.	10.8	1417	77.17	3.4	A
6 N.	8.72	1408	76.23	19.5	F
Average	9.82	1418	76.68	.....	.....
7 S.	12.09	1967	85.78	2.8	F-60-P
8 N.	9.87	1977	85.18	21.2	F
9 S.	11.99	1981	86.06	6.6	F-20-P
Average	10.96	1976	85.55	.....	.....
10 N.	11.10	2499	92.42	16.5	F-10-P
11 S.	12.56	2502	92.83	6	F-20-P
12 N.	11.41	2497	92.51	17.7	F
13 S.	12.24	2492	92.68	9.9	F-30-P
Average	11.91	2499	92.66	.....	.....

TABLE IV.

Calculations for Corrected S.H.P. (First Method).

Knots	E.H.P.	P_w	E.H.P. + P_w	S.H.P.$_1$	S.H.P.$_2$
I	II	III	IV = II + III	V	$V = \frac{V \times II}{IV}$
7.8	430	79	509	739	624
8.71	590	131	721	1036	848
8.83	620	61	681	1058	963
9.82	860	72	932	1418	1309
10.96	1220	65	1285	1979	1876
11.91	1580	21	1601	2490	2465

P_w = Horsepower required to overcome increase resistance due to wind Column XIII of Table III.

S.H.P.$_1$ = Average shaft horsepower for group of runs from Table II.

S.H.P.$_2$ = Corrected S.H.P.

TABLE V.

Calculations for Corrected R.P.M. (First Method).

Knots	R.P.M.	S.H.P.$_1$	S.H.P.$_2$	$\frac{S.H.P._2}{S.H.P._1}\left(\frac{S.H.P._2}{S.H.P._1}\right)^{.205}$	R.P.M.$_2$	
I	II	III	IV	$V = \frac{IV}{III}$	VI	VII = II × VI
7.8	61.82	739	624	.844	.963	59.6
8.71	68.72	1036	848	.819	.957	65.75
8.83	69.31	1058	963	.910	.98	67.90
9.82	76.68	1418	1309	.924	.981	75.25
10.96	85.55	1981	1876	.947	.987	84.40
11.91	92.66	2499	2465	.987	.997	92.20

R.P.M. = Average revolutions for group of runs from Table II.

S.H.P.$_1$ = Average shaft horsepower for group of runs from Table II.

S.H.P.$_2$ = Corrected shaft horsepower for group of runs from Table IV.

R.P.M.$_2$ = Corrected revolutions for group of runs.

TABLE III

CALCULATIONS FOR INCREASE E.H.P DUE TO WIND (FIRST METHOD)

A = 1513 Sq. Ft. .00001227 x 1513 = .01855, AIR HP = .01855 x V_a^3

DATE	RUN	SPEED OF RELATIVE WIND IN KNOTS	DIRECTION OF RELATIVE WIND.		CORRECTION FACTOR FOR DIRECTION		AIR HORSE POWER INCLUDING WIND	SPEED OVER GROUND ON RUN		AIR HORSE POWER NO WIND	INCREASE IN E.H.P DUE TO WIND	AVERAGE INCREASE IN E.H.P FOR GROUP	AVERAGE SPEED FOR EACH GROUP OF RUNS
		V_a		V_a^3	C	$V_a^3 \times C$	P_{aw}	V_o	V_o^3	P_a	P_w	Average P_w	V
I	II	III	IV	V	VI	VII = V x VI	VIII = .01855 x VII	IX	X	XI = .01855 x X	XII = VIII - XI	XIII	XIV
Oct. 8-1931	1N	26.1	F-40°-P	17780	+1.07	19010	352	7.25	381	7	345		
	2S	20.9	A-50°-S	9129	- .90	-8220	-153	8.21	553	10	-163	79	7.8
	3N	24.7	F-35°-P	15070	+1.09	16440	304	7.52	425	8	296		
	4S	13	A-70°-S	2199	- .35	-769	-14	7.88	489	9	-23		
	5N	24.5	F-30°-P	14106	+1.09	16020	297	8.54	623	12	285	131	8.71
Oct. 9 - 1931	1S	12.2	A-40°-P	1816	-1.07	-1925	-36	9.43	836	16	-52		
	2N	24	F-25°-S	13824	+1.07	14800	274	8.13	539	10	264	61	8.83
	3S	8.6	A-40°-P	638	-1.07	-680	-13	9.62	890	17	-30		
	4N	23.2	F-15°-P	12487	+1.02	12740	236	8.97	722	13	223		
	5S	3.4	A	39.3	-1.0	-39.3	-1	10.8	1260	24	-25	72	9.82
	6N	19.5	F	7415	+1.0	7415	137	8.72	663	12	115		
	7S	2.8	F-60°-P	21.9	+.67	14.7	0	12.09	1767	33	-33		
	8N	21.2	F	9528	+1.0	9528	177	9.87	963	18	159	65	10.96
	9S	6.6	F-20°-P	287	+1.04	298	6	11.99	1724	32	-26		
	10N	16.5	F-10°-P	4492	+1.0	4492	83	11.10	1368	25	58		
	11S	6	F-20°-P	216	+1.04	225	4	12.56	1981	37	-33	21	11.91
	12N	17.7	F	5545	+1.0	5545	103	11.41	1485	28	75		
	13S	9.9	F-30°-P	970	+1.10	1067	20	12.24	1885	35	-15		

TABLE VI

CALCULATIONS FOR CORRECTED S.H.P. AND AVERAGE SPEED (SECOND METHOD)

R.P.M	$S.H.P_N$	$S.H.P_S$			CORRECTED S.H.P = $S.H.P_2$	V_N	V_S	V_I
I	II	III	IV = II - III	V = IV / 4	VI = III + V	VII	VIII	IX = (VII + VIII) / 2

R.P.M.	$S.H.P._N$	$S.H.P._S$			$S.H.P._2$ = S.H.P.	V_N	V_S	V_1
I	II	III	IV = II − III	V = IV/4	VI = III + V	VII	VIII	IX = (VII + VIII)/2
62.5	805	725	80	20	745	7.50	8.18	7.84
65	910	830	80	20	850	7.97	8.42	8.19
70	1115	1050	65	16	1066	8.30	9.50	8.90
75	1360	1300	60	15	1315	8.74	10.42	9.58
80	1645	1585	60	15	1600	9.23	11.25	10.24
85	1965	1910	55	14	1924	9.84	11.90	10.89
90	2315	2275	40	10	2285	10.68	12.30	14.49
92.5	2500	2475	25	6	2481	11.25	12.40	11.82

TABLE VII

CALCULATIONS FOR CORRECTED SPEEDS (SECOND METHOD)

R.P.M.	V_1*	$S.H.P._2$*	$S.H.P._N$*	$S.H.P._S$*	$\frac{SHP_2 \times V_1}{SHP_N}$	$\frac{SHP_2 \times V_1}{SHP_S}$	Speed Correction Factor		Speeds		Corrected Speeds		
							North Runs	South Runs	North V_N*	South V_S*	V_N	V_S	Average V
I	II	III	IV	V	VI = (II × III)/IV	VII = (II × III)/V	VIII = II − VI	IX = II − VII	X	XI	XII = X + VIII	XIII = XI + IX	XIV = (XII + XIII)/2
62.5	7.84	745	805	725	7.26	8.06	.58	−.22	7.50	8.18	8.08	7.96	8.02
65	8.19	850	910	830	7.65	8.38	.54	−.19	7.97	8.42	8.51	8.23	8.37
70	8.90	1066	1115	1050	8.51	9.04	.39	−.14	8.30	9.50	8.69	9.36	9.02
75	9.58	1315	1360	1300	9.26	9.69	.32	−.11	8.74	10.42	9.06	10.32	9.69
80	10.24	1600	1645	1585	9.96	10.33	.28	−.09	9.23	11.25	9.51	11.16	10.33
85	10.89	1924	1965	1910	10.66	10.96	.23	−.07	9.84	11.90	10.07	11.83	10.95
90	11.49	2285	2315	2275	11.33	11.54	.16	−.05	10.68	12.30	10.84	12.25	11.58
92.5	11.82	2481	2500	2475	11.74	11.85	.08	−.03	11.23	12.40	11.31	12.37	11.84

* FROM TABLE VI

TABLE VIII.

Comparison of Corrected S.H.P. by Various Methods.

Speed Knots	Corrected S.H.P.				
				Stevens	
	Eggert	Schoenherr	Taylor	1st Method	2nd Method
8	735	750	.....	700	743
9	1020	1060	1065	1000	1060
10	1390	1445	1460	1400	1460
11	1880	1930	1965	1910	1960
11.5	2160	2210	2250	2210	2265
11.75	2320	2350	.....	2370	2415

TABLE IX.

Comparison of Corrected R.P.M. by Various Methods.

Speed Knots	Corrected R.P.M.				
				Stevens	
	Eggert	Schoenherr	Taylor	1st Method	2nd Method
8	62.3	62	.....	61.4	62.3
9	70	70	70	69.1	69.9
10	77.6	77.6	77.6	76.7	77.6
11	85.2	85.5	85.5	84.5	85.5
11.5	89.1	89.3	89.5	88.7	89.7
11.75	91	91.2	.....	91.2	91.6

INSPECTION OF OUR NAVY YARDS—1935.

By Lieut. Comdr. R. J. Walker, U. S. Navy, Member.

Today our Navy Yards are not only taking care of the repair and upkeep of 169 vessels in active commission but are in the process of laying down and building 47 ships which ultimately will cost in round figures $228,000,000. It is on account of this heavy work load that the plant equipment of the various yards is being taxed to the limit; a limit which causes those who are responsible for its adequacy considerable concern.

After the passage of the four-point-eight bill a request was made on the Federal Relief Administration to set up a project for the purchase of $24,663,880 worth of machine tools to rehabilitate the various Naval Shore Stations. Had such a sum been appropriated the average age of equipment ashore could have been reduced from 19 years to approximately 10 years. Much of the old and obsolete equipment which is so costly and slow to operate, to say nothing of its inaccuracy, could have been replaced. Unfortunately this sum was never approved, probably because the cost per man per year for building machine tools was too high. Cost figures based on F. E. R. A. instruction amounted to $21,343 per man per year, those based on Department of Commerce statistics were $1,720 per man per year. Neither of these were low enough to come under the $1,370 per man per year to give 3,500,000 men employment with the $4,800,000,000 appropriated for relief by Congress.

In contemplating an inspection of the machine tool equipment at the Navy Yards in the summer of 1935 the Navy Department was most fortunate in obtaining from the Department of Commerce the services of Mr. R. E. W. Harrison, then in charge of the Machinery Division of that Department.

Mr. Harrison's whole life's work has been devoted to shop equipment. Before joining the engineering staff of The Cincinnati Mill-

ing Machine Company in 1926 where he had charge of the development of their line of grinders, he was engaged as Assistant Works Manager of Churchill Machine Tool Company Works at Broadheath, England, as well as making a technical study of machine shop conditions in France, Holland, Belgium and the United States. While with the Department of Commerce he was most active in stabilizing machinery conditions in this country and promoting sales abroad. His work with the War Department in assisting them with their P. W. A. machine tool program and making a survey of the shell manufacturing operations at Frankford Arsenal was greatly appreciated.

So it may be seen that Mr. Harrison was particularly well fitted to inspect and comment upon the manufacturing technique used, as well as the quality of mechanical equipment now available in our Navy Yards for the accomplishment of their mission.

Having obtained his services, the Navy Department ordered an inspection of the machine tool equipment at the Continental Yards beginning in June of 1935.

The inspecting party in general consisted of Mr. R. E. W. Harrison (Chief of Machinery Division, Department of Commerce), Lieutenant Commander Robert J. Walker, U. S. N. (Officer-in-Charge of machine tools and manufacturing section and representative of the Bureau of Engineering), Lieutenant Commander DeWitt C. Redgrave, (CC) U. S. N. (Assistant to Officer-in-Charge and representative of the Bureau of Construction and Repair), and Mr. Eugene G. Herndon, Senior Mechanical Engineer, Shore Establishments Division (Machine Tools).

From orders and conferences held prior to the inspection trip it was understood that the Department desired to accomplish the following with respect to machine tool equipment and use of same:

I. Maintain machine tools in all yards to a standard that would insure—

(*a*) Sufficient number of each type of tool to handle work load required or in prospect.

(*b*) Accurate machining.

(*c*) Economy in production.

(*d*) Safety in operation.

II. Maintain personnel in all yards to a standard that would insure—

(*a*) An up-to-date knowledge of the art of working materials.

(*b*) Intelligent use of equipment.

(*c*) Economic use of equipment.

Basing on these instructions the inspection was made in as much detail as time permitted. The yards prepared themselves for the visiting party in the same manner as outlined under " Fleet Repair Facilities Ashore " as published in the United States Naval Institute Proceedings, August, 1935.

In passing it is well to mention that the conditions as illustrated in that issue have not materially changed.

The first Navy Yard visited was Portsmouth, N. H., named after the town lying directly across from it on the mouth of the Piscataqua River. The old and rugged granite buildings of the yard quickly took us back to the days of 1820-40 when men were men and work during the winter months began one hour after sunrise and lasted until sunset with one hour for dinner and in the summer began at six A.M. and lasted until six P.M. with an hour out for breakfast and dinner. Then men were only excused from work when the black ball on the flag pole showed that the temperature was 5 degrees or more below zero. The daily rate of pay in those days varied from a minimum of $1.00 to a maximum of $1.75.

The men of this locality have been building boats ever since 1645. It is little wonder that they take such a great amount of interest in their work. It is born in their blood. Today the building of our government constructed submarines is turned over to their careful workmanship. The various and sundry electrical fittings used throughout our service are made here. What a surprise John Paul Jones would have had when he was fitting out the *America* at Portsmouth in 1781 if he had seen the electrical running lights as they are now turning out in this yard.

The equipment at Portsmouth was found in proportion to the age of the buildings to be about as old, averaging eighteen and a half years. Outside of welding equipment their greatest need was for such tools as an open side planer, a boring mill and engine lathes.

The inspecting party hated to leave the beautiful green lawns of Portsmouth and the balmy sea air of the Maine coast for yards further south hemmed in by the smoky industrial centers.

At Boston we found them energetically engaged in building four destroyers. The rope walk built in 1836 with its machinery, average age 32 years, astounded us. The men in the structural shop were busy in working out their never ending jig-saw puzzle of how to maneuver large plates from one machine to another without hitting the uprights or supporting columns of a building which was designed back in the days of wooden ships. The average age of equipment in this yard we found to be twenty-one years, which is older than at other yards, probably due to a lesser need for equipment since the war than our west coast yards which have been kept busy repairing the fleet.

The Navy Yard at Boston like Portsmouth started its being as a naval base in 1800 when the government purchased some sixty-five odd acres of ground at the confluence of the Charles and Mystic Rivers on land formerly known as Moultons Point. A dry dock built of granite was started in this yard in 1827. Its first ship was the *Constitution* (*Old Ironsides*) June 24, 1833.

Our next stop was at the Navy Yard New York over on the Long Island side of the East River near the Brooklyn Bridge. It is one of the most historic, important and interesting spots in greater New York. Yet it is safe to say that the great majority of the dwellers of the metropolis have never visited it.

The most memorable historical association of the place is a sad one. In Wallabout Bay—the old Dutch name for this inlet of the East River—were anchored the terrible prison ships of the Revolutionary War. Most famous, or most infamous, was the *Jersey*, the hulk of an old sixty-four gun vessel, in which more than a thousand captured patriots were confined at one time. Prisoners of war do not fare sumptuously today, but a hundred and twenty years ago their sufferings were horrible. Scantily fed, and herded together worse than slaves ever were, they were scourged, in their cramped and filthy quarters, by dysentery, prison fever and smallpox. "Down, rebels, down!" was their guards' order at night, and in the morning, "Rebels, turn out your dead!" The dead were taken ashore, sewed up in blankets, and buried in shallow graves

in the sand. It is said that from the *Jersey* alone there were taken, during the war, eleven thousand bodies.

The first piece of property for the the Navy Yard was purchased in 1801, about thirty acres for $40,000. In 1806-07 the present Commandant's house was built. Unfortunately for many of the shops the buildings which house them were built before the Civil War and as a result are entirely unsuited for the work being undertaken in them. No appreciable sum has ever been appropriated at one time for the complete rebuilding and rearrangement of buildings in this most important yard. The equipment of the machine shops, the largest of any in our Navy Yards, is a disgrace to the beautiful skyscrapers which shield it from the setting sun. Imagine trying to build large Diesel engines and powerful turbines in a shop where the machine tools average nineteen years of age.

At this point it is well to quote one sentence from Mr. Harrison's report upon the completion of the first three yards: "Evidence grows of the desirability of a thorough clean-up of all old buildings and equipment, yard by yard."

Our next stop found us in the Philadelphia Navy Yard situated on League Island, in the Delaware River. The entire Island originally a marsh flat, but now raised and enclosed by dikes, was purchased in 1863 by the city of Philadelphia for $430,000 and tendered as a free gift to the United States. Because its acceptance by the government would have affected the interests of other places which hoped to be selected, it was vehemently opposed. However, in the end the case was made so clear that on December 3, 1868, the Secretary of the Navy, under authority of Congress, formally accepted the site. Today it is the nearest yard to the center of the steel industry. Its long water route distance from the sea gives it a good natural protection from invading men of war.

The buildings of this yard being of a more recent vintage are more adaptable to the work on hand. The Philadelphia Yard is at present building two cruisers, two destroyers, and four cruising cutters, a load which employs every tool available.

Going down the coast we found the Norfolk Navy Yard located at a place known in the early days as Gosport, Va. No naval shipbuilding and repair base belonging to the United States is more important than this one. Located near enough to the entrance

of the Chesapeake Bay to be easily accessible, it is, at the same time, in a position readily defended from attacks either by land or by water, and, as has been repeatedly shown, can be held by a small force against a very largely superior one. Such is the mildness of the climate that work of all sorts can be carried on at all seasons of the year without interruption. Hampton Roads, the outer harbor, is an excellent point of rendezvous for a fleet or squadron.

Just before the breaking out of the war of the Revolution, the British established a Marine Yard, for the use of their Navy, on the site of the present Navy Yard at Gosport, now a part of Portsmouth, Va. It is stated in a letter, now on file in the Navy Department, written in 1824 by Miles King, United State Navy Agent, that this site was selected after a careful survey of all the ports within its dominions in North America, as the most eligible situation for a naval station. The name of Gosport was doubtless taken from Gosport, near Portsmouth, England, where one of the most important of the British dock yards is located.

Mr. King's letter further states that scarcely had the British government commenced the works when the Revolution began, and the yard, together with the adjoining property of Andrew Sprowle, the British Navy Agent, became confiscated and forfeited to the State of Virginia.

Up to 1799 the Gosport Yard became so well established that the Secretary of the Navy resolved to make it one of the permanent navy yards of the country. At his suggestion the Legislature of Virginia, by an act dated January 25, 1800, ceded to the United States the property known as Gosport for the purpose of establishing a navy yard there.

Today many of the old original granite and brick buildings are still standing. Although these old structures are widely separated from the new foundry, sheet metal shop, machine shop and structural shop, they still have to be used to house the administration offices, paint shop, etc.

The Navy Yard at Charleston, S. C., we found very busily engaged in building a 2000-ton gun boat and a coast guard cutter, with hopes of being given a destroyer to build in the fall. This wish has been granted. The personnel's determined desire to over-

come all obstacles will no doubt enable them to do a good job with the scanty equipment available for such purposes at this yard.

With our visit to Mare Island, California, we found the same condition existing as at Norfolk—the main shops widely separated from each other and from the administration building.

Mare Island and Puget Sound being the closest to the fleet have the heaviest work loads of any of our Navy Yards and have had since about 1925. As a result their requests for new equipment have been given more consideration. Undoubtedly these two yards are the best equipped of any, with Puget Sound leading as the best laid out yard, its activities all being centralized about its docks and fitting out piers.

Being the only two yards on the west coast, and both situated on large land locked bodies of water, their natural location is of extreme importance.

The management and personnel of both of these yards although separated by many miles from our industrial centers are alert to advantages of new processes and improved technique in the working of materials.

To perfect the layout of new buildings in our Navy Yards and the equipment in these buildings, it might be well to adopt a policy similar to that of the Santa Fe Railroad, which has some of the best railroad shops in the country.

Along this line it has been suggested that our ten Navy Yards be divided into two groups of five each, the principal yards in one group and the secondary or smaller in another. Instead of the Navy Yards having moneys for remodeling old buildings, building lean-tos and buying new equipment distributed more or less evenly among them each year, that each five years, after careful planning, the total five-year accumulated money for buildings and equipment be spent in one major yard and one minor yard in rotation.

How much better off our Navy Yards would be today if such a policy had been adopted after the Civil War with adequate moneys supplied periodically by Congress! Lean-tos, make-shift jobs on old narrow buildings with little natural lighting, poorly equipped shops separated by miles of land from building ways and dry docks would not be in existence. In fact, fifty years of such a system with proper funds for executing it would have made Uncle Sam

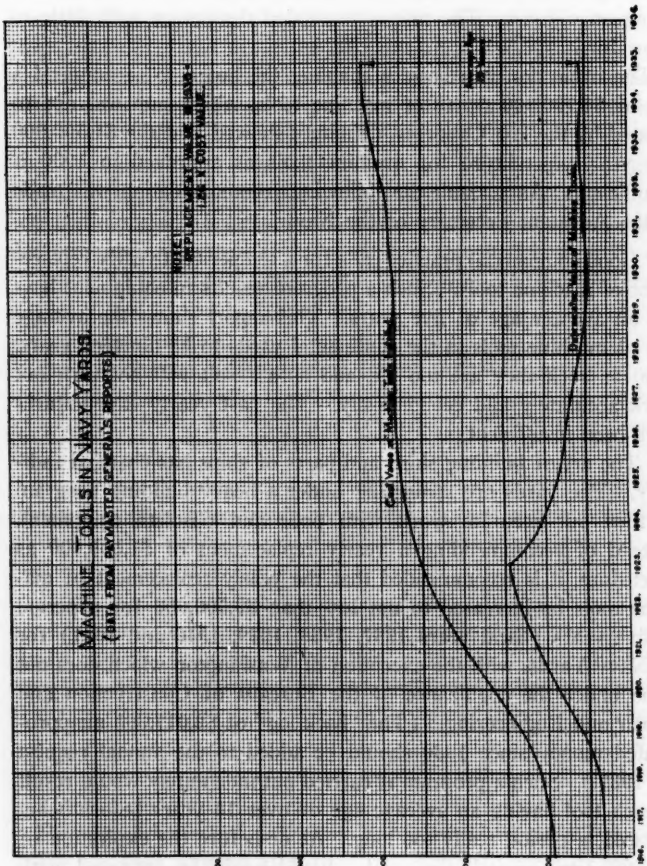
proud of his Navy Yards and they would be prepared at all times to handle expeditiously and economically any existing emergency. Nursing along old buildings with the changing times is like nursing along an old car. The money expended disappears with little to show for it.

The inspection trip besides enabling the board to recommend a list of $1,700,000 worth of machine tools, which sum was appropriated by the last Congress, definitely showed that the $1,500,000 per year expenditure for machine tools as approved in 1930 is insufficient. As a result the following recommendation was made to the Assistant Secretary of the Navy:

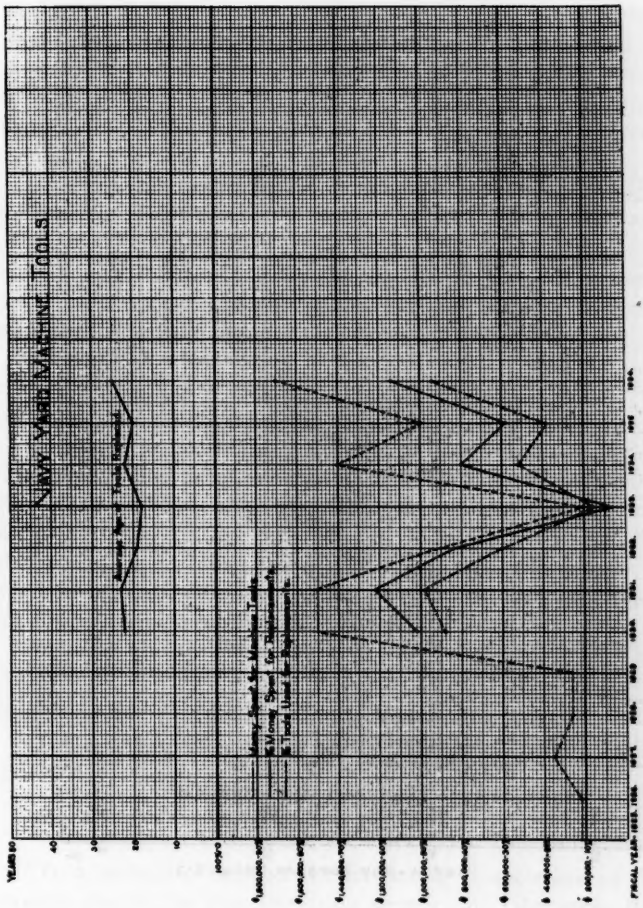
" Good commercial practice calls for a ten per cent yearly replacement of machine tools. Such a program results in equipment having an average age of five years. This report shows the average age of machine tools in the continental yards to be nineteen years. That as such they are too old and as a result will not turn out work accurately and economically. The past yearly expenditures have been insufficient.

" The art of building ships and parts of ships has changed radically. The yards are struggling under a heavy building program to turn out accurate work with poor and obsolete equipment. Instead of recommending a yearly replacement of $1,500,000 as heretofore, it is recommended that the yearly replacement of machine tools be increased to not less than $2,500,000 for a period of five years (fiscal years 1937, 1938, 1939, 1940 and 1941) for all Navy Yards, with the exception of Washington which does not come under the cognizance of the Bureaus of Construction and Repair and Engineering. (The ' back log ' of $2,017,305 unappropriated money since 1930 should be added to the annual request for 1937.) Such a program if carried out indefinitely would result in each tool having an average age of over 15 years before being replaced, a period really too long. At or before the expiration of this five-year period, the yards should again be surveyed with respect to equipment and work on hand or in prospect and the replacement program revised accordingly."

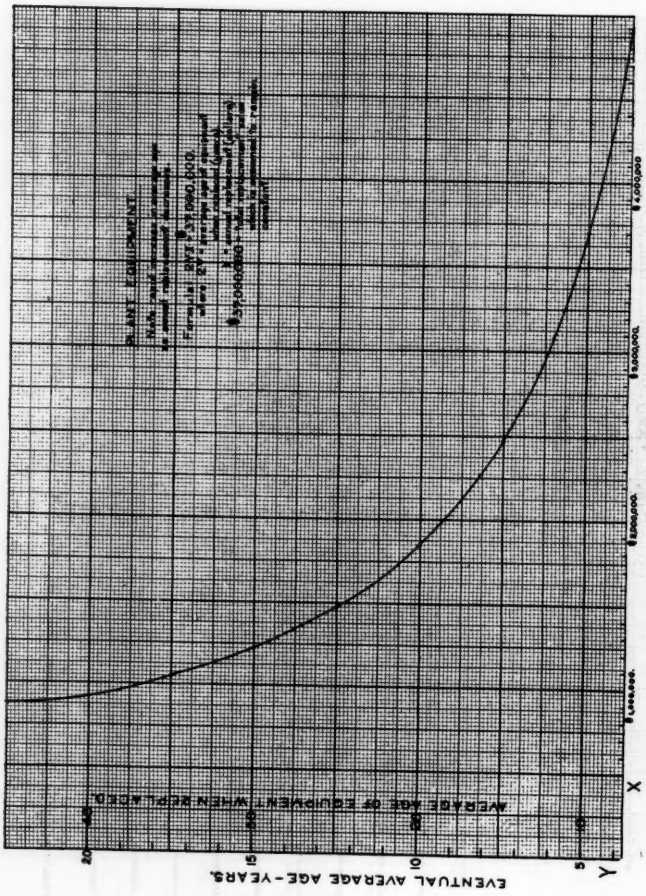
In connection with the changing value of equipment in Our Navy Yards compared to the depreciated value, it is interesting to note the curves and tables of this article.


MACHINE TOOLS IN NAVY YARDS.
(DATA FROM PAYMASTER GENERAL'S REPORTS)
NOTE:
Real Value of Machine Tools Installed.
Book Value of Machine Tools

CURVE No. 1.



CURVE No. 2.



ANNUAL REPLACEMENT.
CURVE No. 3.

Curve No. 1 shows the Cost Value of Machine Tools Installed in the Yards from 1916 to 1935 as well as the Depreciated Value. The fact that the two curves shown in No. 1 are diverging definitely proves that the moneys being expended for Machine Tools in Our Navy Yards are insufficient to reduce the present average age of 19 years, in fact will not even hold the already too great average age to that figure. The curve for the Depreciated Value breaks sharply in 1923 due to the fact that the Depreciation Table was changed.

The curves illustrated by No. 2 graph show the moneys spent for Machine Tools from 1925 to 1936 as well as the average age of the tools replaced. From them it may be seen that from 1930 to 1936 only 47 per cent of the money expended went for replacements and the balance of 53 per cent went for new and additional equipment required mostly for the increased ship building activities.

Curve No. 3 is convincing in that it shows the rapid increase that results in the average age of Machine Tools if insufficient moneys are not forthcoming for replacements.

The American Machinist in 1935 made a survey of the age of equipment in the metal working industry throughout the United States. According to this survey 65 per cent of the machine tools are over 10 years of age. At the end of the fiscal year 1936, 72 per cent of the machine tools in the Navy Yards will be over 10 years of age. In other words, our Navy Yards are much worse off for new equipment than the country is at large.

For those who are interested in an outsider's comments on Our Navy Yards, the main portion of Mr. R. E. W. Harrison's report is quoted *verbatim,* as follows:

"Subject: Inspection of Mechanical Equipment Used in United States Navy Yards.

"ACCURACY.

"To a mechanical engineer the outstanding characteristic of the modern ship is the ever increasing accuracy of fabrication, this applying in varying degrees from the firing and steering control apparatus, all the way down the line to the engine room, and even to the hull itself.

"By accuracy is meant the control of dimensions within close limits of size.

"Without exception this accuracy is dependent on two factors; first, the machine tools used to effect fabrication and, secondly, the human element which uses the machine tools and the hand-operated measuring tools.

"An unmistakable tendency is apparent—the requirements in the way of accuracy are following a well defined trend and the equipment of the immediate and distant future will impose a greater demand than before, hence it is imperative that both the machine and human elements be prepared to meet and, if possible, anticipate this demand.

"If the foregoing basis of thought is accepted, the following conclusions appear to be inescapable:

"QUALITY.

"1. The finest quality of machine tools which the country can produce are none too good for the service which is demanded from them.

"2. Tools of secondary quality or tools which have become inaccurate, through due or undue wear, can only be used when the personnel element is skilled enough to inject the required degree of accuracy by hand; an extremely slow and disproportionately expensive process.

"PRODUCTIVENESS.

"3. While it is not economically feasible to use the type of machine tool which is used in mass production industry, it is, however, necessary that the machine tools which are used in both shore and floating establishments be of such productive efficiency that they will meet the needs of each individual case in respect to the time required to do the work, *i.e.*, economically in time of peace, and expeditiously and reliably in time of emergency.

"NUMBER OF MACHINE TOOLS AVAILABLE.

"4. The machine tool equipment of the United States Navy Yards is inadequate in quantity, and difficulty is experienced in meeting shipbuilding schedules because there is in all shops a shortage of essential tools.

"QUALITY OF MACHINE TOOLS IN USE.

"5. An extremely large proportion of the equipment in use is obsolete, because of its age. (Average age is 19 years.) During the intervening period the original accuracy characteristic has been lost, and in many cases it was never possessed in the degree required today.

"TECHNIQUE.

"Developments which have taken place in respect to technique have in many instances brought about an entire change in the methods of fabrication on parallelling work in commercial establishments: Welding as against riveting; grinding as against turning; milling as against shaping; broaching as against milling and shaping.

"In a number of instances metallurgical advances have made desirable the use of different methods and tools. For instance, the present availability of the Tungsten and Tantalum Carbide cutting elements which are capable of removing metal at rates 3 to 4 times those possible on comparable work when using high speed steel.

"The net result is that while the final results as now obtained are acceptable and in accordance with specifications, the time and skill elements are over-emphasized, costs are higher than they might be if more modern equipment were used, but what is probably of greater importance from the purely military point of view, *there exists an unnecessarily high degree of hazard,* which quite conceivably might assume serious proportions if the yards should, as they undoubtedly will some day, be faced with a military emergency.

"PERSONNEL.

"(Civilian—Supervisory.)

"6. There is an invariable tendency in all establishments (civil and otherwise) where the supervisory element has little contact with competitive enterprise, for an atmosphere of undue conservatism to prevail and this invariably expresses itself in a slowness to adopt new methods as and when they become available. An evidence of this in so far as the Navy Yards are concerned is the

lack of precision grinding equipment, a type which has during the last 15 years rapidly assumed *the position* of prime importance in competitive industry.

"While it is readily agreed that the yards could at no time use such equipment to the extent to which it is used in commercial manufacturing establishments, the fact remains that a great many cylindrical surfaces, internal and external, are being produced by the older methods, whereas much time could be saved and greater accuracy secured if such work were finished in precision grinding machines. The same thought applies equally to the generation of plane surfaces.

"It is suggested that the most effective way of remedying these conditions is by the educational process, *i.e.,* more contact with competitive industry, plus a policy of encouragement at headquarters, which will serve as an inducement to all supervisors to request this more up-to-date equipment.

"EDUCATION FOR EXECUTIVES.

"7. The foregoing suggestion, however, is not the complete answer inasmuch as the need is apparent for a greater degree of appreciation of managerial responsibility on the part of all concerned and to meet this situation it is suggested that a scheme of systematic foreman and supervisors' training be installed similar to that which has been so successfully installed by the General Motors Corporation.

"PLANNING AND PROCESSING.

"(Machining Operations.)

"8. In some cases the processing of work could be more efficiently taken care of, *i.e.,* work is routed to machines which are not the best for the particular operation involved, and speeds and feeds are used which will not give the best results. The suggested remedy for this is almost 100 per cent educational by:

"1. Provision of a suitable training course.

"2. Encouragement to read and learn by the circulation of technical magazines like the 'American Machinist,' 'Machinery,' etc.

"3. Encouragement of participation in Technical Society activities.

"OFFICER PERSONNEL.

"9. While the influence exercised by the Officer Personnel at the yards is wholly good, it is impossible for the urge for, and conception of, an improved manufacturing technique to come from this element under the present system of rotative appointments.

"The working and processing of metals and fabrics has become an exact science which for its fullest expression demands specialization to the last degree.

"It is the writer's belief that it would be in the interests of the Department for a section of the Officer Personnel to be suitably trained on a professional basis and then permanently assigned to meet this professional requirement.

"APPROPRIATIONS.

"10. Having regard to the speed at which the technique of manufacture is changing, as well as the rapid evolution which is occurring in the methods and material of modern warfare, the fact becomes patent that not only the maintenance, but also the improvement of the machine tool equipment in shore establishments should be a continuing activity.

"With this thought in mind the writer, therefore, recommends that a regular yearly appropriation be made to be used exclusively for new machine tool and work processing equipment, this appropriation being on the same regular and undisputed basis as that which is devoted to the payment of salaries. Without continuity of effort in the direction of improvement of technique, costs are increased disproportionately and, furthermore, a situation is likely to be engendered which, in the event of a national emergency, would prove a definite handicap.

"PRODUCTION CONTROL.

"11. One of the regulatory paragraphs appended to all Navy Department appropriations precludes the use of time study equipment such as that which is used in commercial establishments.

"Such restriction imposes on the officials responsible for efficient production a handicap, and deprives them of a tool of management for which there is absolutely *no* effective substitute.

"It is, therefore, recommended that in future this restriction be deleted from bills dealing with appropriations, and management personnel be instructed to estimate and allocate times along similar lines to those employed when comparable work is undertaken in private enterprises.

"MACHINERY MAINTENANCE RECORD.

"12. In well managed commercial organizations it is the almost invariable practice for the maintenance department to record in simple log form on cards bearing the plant number of the respective machines, a statement of the cost involved in hours of labor and material provided necessary to keep individual machines in service.

"This record serves a number of useful purposes, chief among which are guidance when purchasing new equipment, efficiency of machine operator, and adequacy of supervision.

"It is recommended that a similar inexpensive and simple system be made part of the regular routine at each Navy Yard. (This practice is now being followed at the Mare Island Yard.)

"INSTALLATION OF NEW MACHINES.

"13. It is recommended that the central office issue standard instructions to all yards dealing with the proper method for the mounting of various types of machine tools.

"RECRUITING OF NEW LABOR.

"14. Despite the fact that the wages paid to skilled machinists in all yards exceed those available to the same class of labor in competitive industry, difficulty is experienced in securing an adequate supply of properly skilled help.

"As there is only one permanent remedy for this condition, it is recommended that apprentice schools be made a part of the regular establishment of all Navy Yards, and a policy be put into operation whereby 10 per cent of the total personnel employed is drawn from the apprentice training schools."

STEAM IN RELATION TO MARINE ENGINEERING.

By Rear Admiral H. G. Bowen, U. S. N., Member.*

(Address delivered at the Bi-centennial of the Anniversary of the Birth of James Watt under the auspices of Lehigh University, Franklin Institute of Pennsylvania, North American Branch of the Newcomen Society of England and the American Society of Mechanical Engineers, 21 January, 1936.)

First, I wish to express my sincere appreciation of the honor accorded me in representing the Navy and the Marine Engineering Profession in general before this distinguished gathering tonight. On this 200th anniversary of the birth of James Watt, it is fitting for all who have profited by the product of his genius to express something of the deep respect and admiration we all feel for the work of that great pioneer of our Mechanical Age. His genius and initiative have contributed profoundly to the amazing developments of the past 100 years, in both the mechanical and electrical fields, and have been a constant source of inspiration to others to follow along the path he defined.

I believe that I may confidently state that in the marine field such developments have been completely revolutionary in character and have changed the whole trend of human endeavor. More emphatically, I may say that the history of civilization has been changed radically thereby. Whether for the better or for worse I cannot positively state. If greater comfort, higher living standards and a general speeding up of the tempo of life in general may be considered as a criterion of advancement then the change is for the better; but whether the entire sum of human happiness has been increased by these changes, I hope that I may be pardoned for expressing a reasonable doubt.

In my own life I have witnessed the final passing of sail, today practically complete. The billowing canvas and the picturesque top hamper of the sailing vessel have given way to the belching smoke pipes, unadorned masts and the drapery of radio antennae. The

* Chief of the Bureau of Engineering.

sooty path or the oil slick of the steamer has penetrated and made commonplace the most remote corners of the Seven Seas. Something of romance, something of mystery, that fired the imagination of our race has been lost. Something of a more practical nature has been lost, too. The propulsive equipment that once soared above the useful space on decks and below has now descended bodily into the hull structure itself and, by its presence there, together with the fuel required for its operation, competes seriously with the demands of the useful load. The time of passage from port to port is now a mere fraction of that required by sail and the leisurely ways of the past are almost forgotten. However, this has not been without compensation, for there are many among us who find a fascination and an interest in the operation of a smooth-running perfectly balanced machine with its appeal to the imagination beyond the power of any other inanimate object.

The fact that the presence of modern propulsive machinery and the fuel for its operation is a regrettable necessity in the hulls of modern vessels, commercial or naval, has really created the profession of the marine engineer and has at the same time made that profession an unenviable one. For the space occupied by that machinery and its weight, together with that of the necessary fuel, constantly infringes upon the demands of the useful load whether it be for the cargo and passengers of the commercial vessel or for the armor and armament of the naval vessel. However, the trials and tribulations of the modern marine engineer cannot be laid at the door of James Watt, for that canny Scot was firmly opposed to two major developments in the latter course of his life, namely, the application of the steam engine to transportation and the constant increase of steam pressure.

I believe that the greatest single contribution to modern marine engineering of this wonderful pioneer consisted in his first separating the condensing operation from the expansion operation. The invention of the jet and surface cooling principles of condensation and the wet air pump were also his. Among others, must be mentioned the piston rod stuffing box, the double acting cylinder, steam jacketing, the steam admission valve with its cut-off, utilizing the expansive power of steam, and the indicator. All such innovations are in use today—more than 100 years later, and have been the

basis for the development of all reciprocating equipment including the internal combustion engine. In view of the bitter battle today between the steam engine and the internal combustion engine, the last point will possibly not be conceded by the internal combustion designers.

The invention of the steam vessel itself has been claimed for one Spaniard, one Frenchman, one Englishman, two Scotchmen, and four Americans. Among these you can take your choice, depending upon which nationality you favor. Furthermore, practically every industrial country has its own inventor of the screw propeller. Even the invention of the tubular boiler is claimed by no less than four. It does not appear profitable to enter into a discussion before this intelligent audience of the proper ownership of these honors. In this country, however, we find the beginning seems to have been made with John Fitch's brass model fitted with wooden side paddle-wheels presented to the American Philosophical Society of Philadelphia in 1785. This model was followed three years later by his commercially successful stern paddle-wheel steamer. It seems appropriate, too, to mention at this point that a twin screw cross geared vessel with a water tube boiler was produced by Colonel John Stevens of Hoboken, a friend of Fitch's, in 1804, and operated on the Hudson. It is claimed that 50 pounds pressure was used on this vessel. A later vessel of Stevens' design, the *Phoenix*, was driven by Fulton out of the Hudson River and down to Philadelphia and is claimed to be the first sea-going steam vessel. In 1806 came the slower but much better known *Clermont* of Fulton. Fitch's machinery and that of Stevens was of American manufacture, but, we must admit, the machinery of Fulton was of Boulton and Watt's best design, with Watt's "wagon type" boiler, made of copper and carrying 5 pounds pressure.

From these crude beginnings, the development was comparatively slow, gauged by more recent progress, and the designs for many years featured mainly Watt's vertical beam engine and Fitch's paddle-wheels with steam generated in horizontal large flue boilers. Boilers gradually became cylindrical as pressure reached 30 pounds and in 1850 one marine boiler is listed at 80 pounds and one at 90 pounds. About 1851 Erasmus Smith designed, and Mott and Ayres of New York built, a horizontal return tube cylindrical

marine boiler with the so-called "wet uptake"—the first known example of the familiar "Scotch" type of boiler. Randolph and Elder of England followed in 1862 with the first double ended "Scotch" boiler.

As previously stated, the credit for the first water tube boiler appears to belong to Colonel John Stevens of Hoboken. Stephen Wilcox placed the first Babcock and Wilcox water tube boiler on the yacht *Reverie* in 1889. William Hoxie improved this design with one installed on the U. S. S. *Alert* in 1895. And one must not forget the installation by Admiral Melville of Charles Ward's water tube coil boiler on the U. S. S. *Monterey* in 1893.

It is believed that Randolph and Elder of England should also be credited with the first successful compound reciprocating marine engine which was designed and built in 1854. This design utilized double the previous steam pressures which had remained at from 15 to 20 pounds. Superheating came in about 1870 with 60 pounds steam pressure, but was ultimately abandoned to be developed years later by the Babcock and Wilcox Company. In 1875 came the first triple expansion reciprocating marine engine with demands for higher pressure steam until 180 pounds was reached.

Development in the marine propulsion field was very rapid from that time on, following improvements in reciprocating engine and boiler designs until 1897 when Sir Charles Parson "stole the show" with his yacht *Turbinia* presented at the Naval Review in 1897, celebrating Queen Victoria's Diamond Jubilee. The death knell of the marine reciprocating steam engine for use in high speed, high-powered modern vessels was sounded then and there. The marine reciprocating engine based on Watt's fundamental designs probably reached its peak in the design of the German *Kaiser Wilhelm, Second* in 1903 with twin quadruple expansion, steepled cylinder engines developing 38,000 indicated horsepower. Many will remember this latter vessel and its sister ship, the *Kronprinzessin Cecilie* when they were engaged in transporting our troops to France during the World War, but renamed by us the *Agememnon* and the *Mt. Vernon.* In our own Navy the reciprocating engine reached its peak in our battleship design with 28,400 indicated horsepower. These engines on the battleships *New York, Oklahoma,* and *Texas,* are still in service.

The pioneer commercial turbine-driven vessel of the merchant marine was the *Victorian* of the Allan Line, using a direct turbine drive and put in operation in 1904. This was followed by the *Virginian* in 1905 by the same Line and later by the Cunard Liner *Carmania* in 1906. At the time of the construction of the *Victorian* 400 tons was the estimate for the saving in weight of the machinery installation over that of an equivalent reciprocating engine equipment—this with a fuel consumption equal to the best the reciprocating engine had ever produced.

Following experimentation with the yacht *Charmian,* the British Admiralty contracted with the Parsons Marine Steam Turbine Company in 1898 to provide turbine machinery for the destroyers *Viper* and *Cobra,* both of which were outstandingly successful on trials. These vessels were, unfortunately, lost at sea in 1901. The *Velox,* having four screws with cruising reciprocating engines, followed and became the first example of a marine reciprocating steam engine exhausting into a turbine. Under the British Admiralty the *Amethyst* in 1904 was the first turbine cruiser and the *Dreadnaught* in 1906 was the first turbine battleship.

In the meantime, Mr. Charles G. Curtis, under patents granted in 1896, was perfecting in the United States his pressure staged and velocity compounded impulse turbine design. The first vessel built having this type of turbine is believed to have been the yacht *Revolution,* completed in 1902, but which was not very successful, primarily due to poor model design.

In our Navy the steam reciprocating engine long remained as the most reliable propelling equipment. The battleship *North Dakota* in 1908 was the first capital ship to have direct drive Curtis turbines, but lack of reliability and small cruising radius resulted in the construction of the battleships *New York* and *Texas* in 1912, and the *Oklahoma* in 1914, with reciprocating engines. However, a sister ship of the *Oklahoma,* namely the *Nevada,* was fitted with Curtis turbines and geared cruising units. These two latter vessels also marked the definite shift from coal to oil fuel in our Navy.

It may be of interest at this time to recall two major engineering experiments conducted at about this time by our Navy. The first was with the cruisers *Birmingham, Chester,* and *Salem.* The *Birmingham* had twin screws fitted with triple expansion recipro-

cating engines. The *Chester* had Parsons direct drive turbines on four shafts, and the *Salem* had Curtis turbines on two shafts with single reduction gears. This first experiment was not especially successful in demonstrating the superiority of the turbine, as the reciprocating engine vessel had a more economical performance at full power. Later, three fuel carrying vessels of the 1911 program were separately engined as follows: the *Cyclops,* a twin-screw vessel, with reciprocating engines; the *Neptune,* two shafts with Parsons turbines and Westinghouse reduction gears; and the *Jupiter,* two shafts with a Curtis turbine generator driving two electric propulsion motors all of General Electric design. The *Jupiter* thus became the first electric drive vessel and is still in service today, though renamed the *Langley.*

It seems appropriate at this point to pay tribute to the outstanding contributions made to the development of the turbine electric marine propulsion equipment by Mr. W. L. R. Emmett of the General Electric Company; also Rear Admiral Hutch I. Cone, Chief of the Bureau of Engineering from 1909 to 1913; the late Rear Admiral Robert S. Griffin, Chief of the Bureau of Engineering from 1913 to 1921; Admiral S. S. Robison, Commanding Officer of the *Jupiter* in 1914, and Rear Admiral S. M. Robinson, first Engineer Officer of the *Jupiter,* all of the U. S. Navy.

The experimental installation on the *Jupiter* was so generally successful that turbine electric propulsion was adopted for capital ship construction in the U. S. Navy, beginning with the battleship *New Mexico,* in 1917, and all later battleships have followed the same design. The highest powered vessels in the U. S. Navy today have electric propulsion, namely, the aircraft carriers, *Lexington* and *Saratoga,* with 180,000 shaft horsepower each. In the merchant marine, turbine electric drive has not been widely used although recently we have all noted the performance of the *Normandie* of the French Line, the highest powered merchant vessel now in operation, which is equipped with turbine electric propulsion of 160,000 shaft horsepower at full power. The British merchant marine has used the turbo electric drive design on several important vessels such as the P. and O. liners of the *Strathnaver* type using 28,000 shaft horsepower, though the latest design on this service, as shown by the *Strathmore* of 1935, is a geared turbine arrangement. Our own merchant marine has employed electric drive up

to 26,500 shaft horsepower for the *President Hoover* and *President Coolidge*. But later designs and designs now contemplated employ geared turbine drive.

Nothing in the history of marine engineering can equal the rapid changes in marine propulsion which have followed the coupling of the turbine to reduction gearing, both single and double, and the development of turbo-generators with main shaft driving motors. Both these methods utilize to the utmost the inherent advantages of high-speed turbines while still retaining the more efficient propeller speeds. Steam pressures and temperatures have increased rapidly, far beyond anything that could have been used to advantage with reciprocating engines; at the same time that the horsepower of vessels has been enormously increased, fuel consumption per horsepower has been decreased thus making it possible to greatly increase the speed of sea-going vessels without infringing on the space and weight required for the useful load. And with all this has come a flexibility of control and a reliability of operation closely paralleling that of the reciprocating steam engine itself which over the years set a standard of reliability that may never be approximated again.

Above all other characteristics of marine machinery, the marine engineer must of necessity put reliability first. Failure of power ashore may occasionally be a serious matter, but it is more likely to be merely a troublesome inconvenience, or, at the worst, result in a slight economical loss. Repair facilities are immediately at hand and the entire industrial equipment of the country is readily available at a price. Not so if power failure occurs at sea where great loss of property and even serious loss of life is frequently a consequence. Consider, too, the case of the Naval vessel, built for one purpose and one only, to defend the Nation against aggression. If such a vessel fails in a crucial moment of a Naval engagement, probably a matter of a few moments or hours at the most, it is worse than a failure—its very construction at all was a menace to the national welfare. Hence, the Naval engineer must always visualize the possible Naval battle for which a Naval vessel is designed and give reliability precedence over all other considerations, even at the expense of economical operation, space and weight. Building fighting vessels within tonnage limits set by International

agreement, with each Nation striving to include the maximum offensive and defensive capabilities within such tonnage limitations, taxes the marine engineering talent of every modern Naval power to the utmost degree. Economy of operation and space and weight requirements have been, during the recent past, just as important in the design of the military ship as in the case of the commercial vessel, but with the added reliability factor demanding infinitely greater consideration. Someone can always be found to underwrite commercial ships and cargoes against loss at sea, but only a Divine power can underwrite the Naval vessel or the Nation which it defends.

It may be well at this point to glance briefly at some design results which indicate progress in Naval engineering in recent years. Considering battleships first, it should be pointed out that none have been built since the Washington Treaty. The design of battleships now in service placed reliability before all other considerations, and this is reflected in the weight of the machinery per horsepower. The average weight per horsepower of battleship propulsion machinery, including all auxiliaries, piping, wiring and electrical equipment complete, before the advent of turbines was about 230 pounds per horsepower. The use of geared turbines reduced this to about 180 pounds per horsepower. The use of the turbo-electric propulsion equipment, however, raised this figure again to about 200 pounds per horsepower, but in the case of high-powered turbo-electric drive vessels, such as the *Saratoga* and *Lexington,* this figure was reduced to less than 100 pounds per S. H. P. Until we reach the re-engined battleships the fuel consumption of this class of machinery has not been materially better than about 1.2 pounds per S. H. P. hour for all purposes, except in the case of the turbo-electric propulsion equipments which closely approximated 1 pound per S. H. P. hour. Recent improvements in the re-engined battleships, however, have reduced this consumption with geared turbine designs down to approximately .9 pound per horsepower hour.

In the cruiser class of vessels, the difference is much more marked. The *Birmingham,* for example, with reciprocating engines required 123 pounds per S. H. P., whereas our modern cruisers with turbines and reduction gearing approximate 40 pounds per

S. H. P. Fuel consumption for this class of vessels has also improved down to approximately .7 pound per S. H. P. hour. For the destroyer class improvements have been still more marked until today we are building destroyers with propulsion machinery approximately 30 pounds per S. H. P. and with fuel consumptions equal to or better than that of the cruisers.

Today we are using steam pressures up to 600 pounds and temperatures up to 700 degrees F. in the Navy and higher temperatures are in use in the commercial marine field. This, it is realized, is very conservative as compared to practice ashore, but this is due to the natural conservativeness or marine design. Still higher pressures and temperatures afloat will arrive, however, in the course of time.

It would not have been possible to have so greatly increased the power of vessels were it not for the substitution of fuel oil for coal. In this country the maximum reached has been in the *Saratoga* and *Lexington,* mentioned previously, with 180,000 S. H. P. each. Try to imagine what it means to concentrate such a tremendous amount of flexible power in the space available in the hull of a fighting vessel where every pound and every cubic foot of propulsive machinery competes directly with every pound and every cubic foot of armor, armament, ammunition, airplanes, bombs, gasoline, and living quarters. The genius of James Watt would find a generous field for endeavor if its like were available in the world today.

The traditions and many of the mechanical principles of the reciprocating steam engine are still carried on today in thousands of applications afloat in the less important and low-powered designs and, combined with the low-pressure turbine, may even compete in important future commercial installations. But the internal combustion engine utilizing many of the conventional design features originated by Watt is now just coming into its own and is competing seriously for supremacy in the field which the advent of the turbine preempted from the reciprocating steam engine.

Our design horizon is now primarily limited by the fundamental limitations of the metals with which we work. The genius of our research workers is constantly widening this horizon by the elimi-

nation of many of our uncertainties. The boiler, the turbine and the internal combustion engine are making demands upon metallurgists for better and better materials in order to achieve heights of power and dependability beyond anything conceived today.

The internal combustion engine challenges seriously the best that boilers and turbines can offer in the marine propulsion field, at least up to about 15,000 S. H. P. This challenge is primarily expressed as an advantage in economy of fuel. But the forced circulation boilers with extremely high pressures and temperatures of steam combined with turbines which can utilize steam with such characteristics are rapidly paralleling the performance of internal combustion engines and may always be expected to compete. In some fields the internal combustion engine is supreme today, primarily perhaps for the submarine type of vessel, for which no other type of drive can seriously be considered. The light, high-speed Diesel engine with suitable arrangements for eliminating dangerous criticals is now dominating certain low power fields. New designs in steam equipment, however, are only a short way behind. The future—what can I say of the future? What can anyone predict as to future developments in this mechanical age of ours as one contemplates the tremendous changes that have taken place since the day of Watt, and particularly during the past 20 years?

I believe that the immediate future will be dominated by steam for marine installations of 10,000 to 15,000 horsepower and higher, including all express liners and combatant vessels of war. Great potentialities exist in the extra high pressure-boiler designs such as the Velox, the Loffler, Benson, and Wagner types of forced circulation boilers now being installed more or less experimentally abroad. This country, too, is rapidly developing designs of similar characteristics. Probably steam pressures will not exceed 700 to 850 pounds, but temperatures will only be limited by the limitations of metal. Much further experimentation is necessary before the full capabilities of extra high-pressure steam can be realized in installations afloat. But, in any case, the signs all point to the fact the steam propulsion is just now entering a completely new development stage which may lead us as far from our present day designs as we have already advanced from the time of James Watt.

CADMIUM PLATING.

By W. P. Barrows and K. D. Williams, Civilian Member.

During the past few years cadmium has been applied extensively, particularly in fields where the protective value of zinc is desired combined with a pleasing appearance. Zinc and cadmium resemble each other both chemically and electro-chemically; both are associated together in nature and most of the commercial supplies of cadmium are recovered as by-products in zinc refining. For several years, these two metals have been competitors in the field of electro-deposition where long time protection against corrosion is desired, zinc because of its cheapness and cadmium by reason of its more pleasing initial appearance. In this article it is planned to give a brief review of the composition and operating conditions of cadmium plating solutions, some of the problems encountered in the use of cadmium together with an account of some recent developments both in research (including thickness measurements of zinc and cadmium coatings), and in the commercial field which may tend to restrict the use of cadmium and to increase the use of zinc. Cadmium has become the universal coating used on the steel parts of electrical fittings used by the Navy. Steel parts such as screws, bolts, nuts and washers used in contact with aluminum alloys have been required to be cadmium plated since the first use of aluminum alloys by the Navy. It has been accepted as a coating for pipe unions and pipe fittings on an equal basis with zinc.

Much misleading information has been spread relative to the difficulties of obtaining satisfactory cadmium plating unless certain proprietary methods were used and much unreliable information has been published relative to the superiority of cadmium plating over zinc plating or coating and *vice versa*.

COMPOSITION OF CADMIUM PLATING SOLUTIONS.

Cadmium, so far as is known, is deposited commercially solely from cyanide baths. Various compositions have been suggested

similar in the main ingredients but varying in concentration. The bath is usually prepared by dissolving cadmium oxide in a solution containing an excess of sodium cyanide. A part of the sodium cyanide combines with the cadmium oxide to form a double cyanide of the formula usually considered as $NaCd(CN)_3$. The rest of the sodium cyanide remains in the solution as "free cyanide" and should be maintained at a definite value. Sodium hydroxide is also formed by the reaction. During the operation of the solution sodium carbonate is formed by absorption of carbon dioxide from the air and the hydrolysis and oxidation of the sodium cyanide. Usually "addition" agents are added to the bath to increase the throwing power and brighteners to increase the brilliance and luster of the deposits. Most of these substances are of organic nature. Some of those suggested are glue casein, wood pulp extract (gulac), turkon oil (sulphorated castor oil). Claussen and Olin (1) have suggested Steffens waste (by-product of the sugar industry) and the concentrated steep water produced by the initial soaking of corn in the starch industry. Westbrook (2) found the use of an inorganic addition agent, nickel as nickel sulphate, beneficial. Most of the supply houses controlling patents on cadmium plating use their own particular brightener.

A typical low concentration cadmium plating solution producing excellent deposits has been maintained within the following limits:

SOLUTION NO 1.

	oz./gal.
Cadmium	2.00– 3.00
Equivalent to cadmium oxide	2.28– 3.42
Total cyanide (calculated as sodium cyanide)	9.00–10.00
Free sodium cyanide	5.00– 9.00
Sodium hydroxide	1.00– 2.00
Sodium carbonate	4.00– 8.00

A suitable "addition" agent.

A high concentration bath has been suggested by Westbrook (2) of the initial composition as follows:

(1) Trans. Am. Electro Chem. Soc., May 15, 1933.

(2) Trans. Am. Electro Chem. Soc., Vol. 55, p. 333, 1929.

SOLUTION No. 2.

	oz./gal.
Cadmium	5.25
Equivalent to cadmium oxide	6.00
Total cyanide (sodium cyanide)	16.10
Free sodium cyanide (calculated)	9.20
Sodium sulphate	6.70
Sodium hydroxide (calculated)	3.74
Nickel sulphate	0.13
Gulac	1.6

Cadmium plating solutions are operated at room temperature (about 70 degrees–90 degrees F.) for the best results. The cathode current densities vary with the concentration of the solution. A low concentration bath such as No. 1 is best operated at about 15.0 amps./ft^2. A high concentration bath such as No. 2 may be operated at higher current densities such as about 20 amps./ft^2 or even higher. No attempt here is made to discuss the advantages and disadvantages of the two types of baths. The material to be plated is prepared for plating by the usual methods of pickling, grinding, polishing and cleaning.

PROBLEMS OF USE.

One problem that has arisen in the use of cadmium plate is the occurrence of a black discoloration of the deposit during storage without air circulation. Soderberg (3) explained this as the action of moist ammonia fumes formed by the disintegration of cyanide or ammonia salt residues on the surfaces of the plate. This condition is undoubtedly intensified by incomplete rinsing after plating and by incomplete removal of the plating solution from parts which tend to trap and retain the solution. Soderberg recommended a short immersion (50 seconds) in a dip containing 20.0 oz./gal. chromic acid and 0.54 oz./gal. sulphuric acid to remove salt residues and which would also act as a bright dip.

Another problem which has arisen in connection with the use of cadmium plate is the formation of a white powder corrosion in closed systems where temperatures above normal may occur and where electrical insulating materials are employed. The explana-

(3) Trans. Am. Electro Chem. Soc., Sept. 26, 1932.

tion offered is that these attacks were caused by the liberation of volatile organic acids, or compounds easily oxidized to form such acids, from the insulating materials themselves or the impregnating compounds. A large number of such insulating materials were tested by heating at various temperatures 120–200 degrees F. in closed systems with cadmium plate. About 35 per cent of the products tested exhibited a capacity to release volatile products which attacked cadmium plate and formed objectionable white powder corrosion products. Among the worst offenders were such insulating materials as oiled linen cloth, impregnated tubing, saturated tubing, varnished cambric, covered wire, oiled (varnished) linen tape, varnished silk tape and varnished duck. It was also found that the cadmium could be protected from these attacks by the use of a suitable phenol condensation lacquer. It is understood that zinc coatings are not subject to similar attacks.

Generally speaking, the problems that arise in the use of cadmium plating are not such problems as have been mentioned above. Neither is the production of good deposits in the plant a serious problem, since a properly controlled cadmium bath offers fewer difficulties in operation than most other plating baths. The nickel plating solution, for example, even though it is one of the oldest known plating solutions, in the opinion of most operators presents more problems than a cadmium bath.

The problems that most frequently arise in the mind of the user are based on such questions as the following:

1. How does cadmium compare as a protection against corrosion with the cheaper material zinc under various conditions of exposure?
2. Is the more pleasing initial appearance of the cadmium worth the increased cost of the material as compared to that of zinc?
3. Shall specifications be made based on the thickness of coating or on salt spray life?
4. If a specification is made based on salt spray life what does it mean in terms of life under atmospheric or sea water exposure conditions?
5. If a specification is made based on the thickness of deposit shall average or minimum thickness be specified; how may thickness be rapidly and conveniently measured and what does it mean in terms of life under various conditions?

TEST RESULTS.

At least some of these questions are in a fair way to being answered as a result of a cooperative research carried out on coated ferrous materials during the past few years by the American Society for Testing Materials and the American Electro Platers Society. This research was carried out under the direction of Dr. Wm. Blum of the Bureau of Standards, and by Mr. Paul W. C. Strausser, Research Associate of the American Electro Platers Society, and by Mr. Abner Brenner of the Bureau of Standards.

During this research, coatings of a known thickness of both zinc and cadmium were deposited on cold rolled steel, S.A.E. 1010, and exposed in the spring of 1932 at various locations as follows:

(1) At Pittsburgh, Pa., and New York City, representing industrial conditions of exposure;

(2) At Sandy Hook, N. J., representing industrial and marine conditions;

(3) At Key West, representing tropical marine conditions;

(4) At Washington, D. C., representing mild urban conditions; and

(5) At State College, Pa., representing rural conditions.

Salt spray (20 per cent at 95 degrees F. + or — 4 degrees F.) and intermittent immersion tests were made on test pieces similar to those used for exposure tests. The conclusions based on the results of these tests were as follows:

1. Thin coatings of either zinc or cadmium furnish better protection against corrosion of steel in most normal climates than do equally thin coatings of copper, nickel or chromium.

2. In a marine or rural atmosphere, either zinc or cadmium coatings with a minimum thickness of 0.0005 inch furnish protection against corrosion for several years.

3. In industrial locations, both zinc and cadmium coatings fail in a comparatively short time.

4. In industrial locations, cadmium coatings fail in about 75 per cent of the time that is required for failure of zinc coatings of the same thickness.

5. Alloy deposits that contain about 10 per cent of cadmium and 90 per cent of zinc have a slightly longer life than either zinc or cadmium.

6. In industrial locations, the protective value of either zinc or cadmium is practically proportional to their thickness.

7. Neither the method of preparing the steel used nor the composition of the zinc or cadmium plating solution in the research referred to has any effect on the protective value of the coating that is comparable with the effect of the thickness.

8. Hot dipped zinc coatings furnish about the same protection as plated zinc coatings of the same thickness.

9. In the salt spray and intermittent immersion tests, the time required for the failure of zinc coatings is approximately proportional to the minimum thickness.

10. Plated zinc coatings fail more rapidly in the intermittent immersion than in the salt spray tests.

11. Neither the salt spray test nor intermittent immersion furnishes a reliable criterion of thickness of cadmium coatings or of their relative protective value to that of zinc in an industrial atmosphere.

12. The average thickness of both zinc and cadmium coatings can be reliably determined by the antimony chloride hydrochloric acid stripping test; and of cadmium coatings by stripping in ammonium nitrate or ammonium per sulphate.

13. The Preece test is fairly accurate measure of the distribution of plated zinc coatings over 0.005 inch thick but not of thinner coatings.

14. The dropping methods with an iodine solution or an ammonium nitrate solution measure the local thickness and distribution of zinc and cadmium coatings with an accuracy of about 15 per cent.

DROPPING TESTS.

Methods of measurements of the distribution and local thickness of zinc and cadmium coatings by rapid and simple methods such as the dropping tests, were developed by Hull and Strausser (4) to meet the requirements of the present tendency to specify the minimum rather than the average thickness of the coatings. The dropping tests, as noted above, measure the thickness and distribution of the coatings within an accuracy of about 15 per cent.

(4) The Monthly Review, American Etlecroplaters Society, Mar., 1935.

Apparatus:

A 250m/*l* separatory funnel is connected by rubber tubing to a two-way stop cock, the lower end of which is drawn down to a tip with an orifice similar to that on the average burette. A glass or porcelain dish is placed under the tip and the specimen is so supported that the drops of liquid run off quickly without touching areas to be subsequently tested. The rubber tubing connecting the funnel and the stop cock may be of some length so that the drops may be directed when testing articles of irregular shape.

Solutions:

(a) For electroplated cadmium

Ammonium nitrate (C.P)	110g/*l*
Hydrochloric acid (sp.gr.1.18)	10ml/*l*

(b) For hot dipped zinc

Ammonium nitrate (C.P.)	100g/*l*
Hydrochloric acid (sp.gr.1.18)	75ml/*l*

(c) For electroplated zinc

Ammonium nitrate (C.P.)	100g/*l*
Nitric acid (sp.gr.1.42)	55ml/*l*

The used solutions shall be discarded.

Preparation of Specimen:

The surface of the specimen should be free from " water break," that is water should wet the entire surface. This condition may be obtained by cleaning with an organic solvent followed by rubbing lightly with a paste of pure magnesium oxide, then rinsing with water. The specimen should then be dried by wiping with a clean cloth.

Temperature:

The room temperature during the test should not be less than 60 degrees F. nor exceed 80 degrees F.

Procedure:

The funnel should be filled with the solution specified for the coating on the specimen. The upper cock should be opened wide and the flow of the solution regulated by the lower cock. The flow from the orifice should not be less than 80 drops per minute and

should not exceed 120 drops per minute. The upper cock should then be closed and the sample placed in position.

The specimen should be supported by a rack, clamp, or any other suitable means so that the portion of the specimen to be tested is about 2 inches below the orifice and so that the solution will run off freely. The time from the first drop striking the specimen to the exposure of the steel should be determined, preferably by the use of a stop watch.

Computing results:

Under the test conditions, each of the solutions dissolves 0.00001 inch of the specified coating per second. If 50 seconds are required to expose the steel, the coating is 0.0005 inch thick.

By the use of this method the surface of the specimen may be explored and the average and the minimum thickness determined. For general service a minimum thickness of coating of 0.0005 inch, for both zinc and cadmium, is required, and for mild service a minimum thickness of coating of 0.00015 inch is required.

As a result of these various tests on zinc and cadmium coatings, the American Society for Testing Materials, and the American Electroplaters Society, with the National Bureau of Standards collaborating, have proposed specifications for both electro-deposited zinc and cadmium coatings on steel based on the *minimum* thickness of the coating, rather than on the average thickness of coating or on salt spray tests.

GENERAL CONCLUSIONS.

The recent use of cadmium for bearing alloys in the automotive industry has caused a severe scarcity of cadmium and very materially increased the price. Moreover, to meet this condition processes have been proposed for the deposition of bright zinc to overcome the objection to the inferior initial appearance of ordinary electro-deposited zinc as compared to that of cadmium.

If these bright zinc deposits prove satisfactory and the scarcity of cadmium continues, these conditions combined with the results of the exposure tests (*i.e.*, that zinc coatings of equal thickness are not inferior to cadmium coatings under either marine or industrial atmospheric exposure conditions and that under industrial atmos-

pheric exposure conditions zinc coatings afford greater protection than those of cadmium) will tend to decrease the use of cadmium coatings and increase the use of zinc coatings for the protection of ferrous metals against corrosion.

It is the popular belief that hot dip galvanizing is superior to zinc electro-plating. This is probably due to the heavier coating usually resulting from the hot dip process. The results of the research indicate that if the same thickness of coating is applied by either the hot dip or electro-plating process the resulting coatings will give equal resistance to corrosion.

Since the results of the exposure tests of the strips of zinc and cadmium coated steel have become available it appears that cadmium coated parts should not be used in locations aboard ship where they may be exposed to smoke or products of combustion. Zinc coatings should give at least 25 per cent longer life under such exposures.

In the electrochemical order of the elements, cadmium and aluminum are given the same value while zinc is slightly electropositive to aluminum. From this it would appear that zinc coated steel would serve equally well with aluminum as cadmium coated steel.

Information relative to the effect the gases generated by electrical insulating materials in enclosures may have on zinc should be further investigated before zinc is used to any appreciable extent in closed receptacles where electrical insulating materials are present.

Both cadmium and zinc are relatively soft metals and will not withstand excessive abrasion wear.

For parts which are to be subsequently painted zinc or cadmium applied by plating retain the paint better than zinc applied by the hot dip method.

It appears that long service life may be expected from steel articles exposed to weather, sea air and sea spray if such articles are coated with at least 0.0005 inch of cadmium or zinc, and that the method used to apply the coatings is of little importance provided an adherent coating, free from blisters or imperfections, is obtained.

DIESEL ENGINES FOR POWER BOATS OF U. S. NAVY.

By E. C. MAGDEBURGER,* MEMBER.

A new chapter is about to be written in the history of ships' boats in the U. S. Navy; beginning with the commissioning of the cruisers and destroyers of the 1933 construction program all new vessels will be equipped with Diesel propelled power boats and the power plants of the existing boats will be changed to Diesel as fast as funds will permit. From oars—to sails—to steam—to gasoline engines—to oil engines. It is therefore fitting to usher in this newcomer with the obituary of its immediate predecessor, the gasoline motor; to review the difficulties which had to be overcome before Dieselization became a reality; and then to introduce the type of Diesel propelling plant as finally adopted.

The ideal power plant for the ship's boat of a combatant vessel must be:

(1) Reliable in performance;
(2) Light in weight;
(3) Compact in space requirements;
(4) Safe in operation;
(5) Economical in fuel consumption, to permit ample cruising radius;
(6) Readily available in emergencies or easily started; and
(7) Capable of being operated by the lowest ratings of the ship's crew.

HISTORICAL SKETCH.

From Oars to Gasoline Engines.

Oars and human muscles can hardly be excelled for reliability and availability, but in weight, space required and endurance the sailor cannot begin to compare with any of his mechanical substitutes. Rowing boats cover a five-mile course used in boat racing in

* Design Division, Bureau of Engineering.

about 1½ hours, while sailing launches do that in half the time under average conditions, but the winds are fickle and unreliable. Steam cutters were therefore designed toward the end of the last century, primarily to tow the sailless sailing launches, but their propelling plant, although reliable, sinned against all of the other essential requirements, and therefore a board appointed by the Commander-in-Chief of the Atlantic Fleet in September, 1907, immediately preceding the celebrated round-the-world trip of the American Armada, recommended the replacements of all steamers, with the exception of one per vessel, by boats with gasoline engines. As the result of this recommendation the battleship *Mississippi* received on 23 July, 1908, the first gasoline engine driven motorboat in the U. S. Navy, a 30-foot commercially built boat with a maximum speed of 10 knots.

By 1910 there were not less than 46 different makes of gasoline engines in service in our Navy and in July of that year the Bureau of Engineering was authorized to design a gasoline engine for motorboat propulsion; the manufacture of which began at the Norfolk Navy Yard in 1911. Thus came into existence the "Norfolk" engine which propelled the naval motorboats for the next twelve years or more. It was of the two-cycle, three-port type, 4½-inch bore, 5-inch stroke, and developed five horsepower per cylinder at 500 R.P.M. It was built in one-, two-, three- and four-cylinder sizes, and was equipped with low-tension magneto ignition and a length of rope to be wound around the flywheel for hand starting. It used the explosive gasoline mixture for scavenging, thereby wasting much gasoline into the exhaust and on a cold morning it could always be relied upon to wake up everybody on board by its frequent backfiring and by the profanity of its operator standing helpless with the rope in his hand.

In 1922 Joseph Van Blerck, a well known marine engine designer, was commissioned to design a more modern motorboat engine for the Navy to be known as the Type V, which since that time has been manufactured at the Norfolk Navy Yard. This engine is of the four-cycle, overhead valve type, 5½-inch bore, 6-inch stroke and was built originally in two, four and six cylinders developing 25, 50 and 100 horsepower at 800 R.P.M. for the first two and 1000 R.P.M. for the V-6. These engines were equipped with

duplex battery, ignition, electric starting and automotive, or sliding-gear type, of reverse gear. However, by 1926 the two-cylinder engine had to be abandoned on account of excessive weight and vibration, and rights were purchased from the Buffalo Gasoline Motor Co. to manufacture at the Norfolk Navy Yard their four-cycle, four-cylinder engine of L-head type, now known as Type BA. This engine is of 3½-inch bore and 5-inch stroke developing 19 horsepower at 900 R.P.M. It is equipped with battery ignition, electric starting and planetary type of reversing gear.

At the present time there are about 1300 standard type gasoline engines in the U. S. Navy, divided about as follows: Type BA–750; type V-4, 250; type V-6, 300. Type BA is installed in 26-foot motorboats and motor launches up to 36-foot, type V-4 in 40-foot and 50-foot motor launches and type V-6 in 35-foot and 40-foot motorboats. There are of course in addition many special boats of various types in the U. S. Navy propelled by gasoline engines of commercial types varying in size from 150 to 700 horsepower, but these are outside of the scope of this article.

Disadvantages of Gasoline as Fuel.

Looking over the essential requirements of a propelling plant for a ship's boat, one must readily admit that the modern motorboat gasoline engine excels in all except that it is definitely unsafe in operation, despite the fact that its cousin on the highways jeopardizes human lives on extremely rare occasions, considering the engine only, not the drivers. The reason for the excessive danger of fire in a motorboat lies, manifestly, in the lack of proper ventilation for the spaces in the immediate vicinity of the engine as compared with the perfect ventilation of these spaces in the automobile. The necessity of protecting the engine from the effects of salt spray and damp air makes the problem of ventilation extremely difficult, particularly if it be kept in mind that the boat's hull effectively restricts natural ventilation and the ever-present bilges require additional means to remove gasoline and its vapors from the vicinity of the engine.

The Bureau's long experience with fires in motorboats has established the fact that by far the most of them occur within ten minutes after fueling, when the boat spaces are still full of the gasoline

vapors as the result of fueling. As long as electric ignition and electric starting are used there will be danger from electric sparks, as long as sailors will neglect keeping the bilges clean there will be gasoline vapors in the bottom of the boat, as long as there will be sailors who will try to improve engine operation by surreptitiously drilling holes in the intake manifold, which is closed by elaborately designed flame arresters, there will be dangerous backfiring, etc. Briefly summarized, the problem of safe operation of motorboat gasoline engines is not impossible but requires eternal vigilance and more conscientious attention than can be expected under average operating conditions in the Navy. It is not surprising, therefore, that consistent efforts have been made for sometime past to eliminate gasoline as the fuel for motorboat engines—this being considered as the only sure way to stop the perennial motorboat fires.

Gasoline Substitutes for Explosion Engines.

Volatility, the very characteristic which makes gasoline dangerous, makes it also the most desirable fuel to use in the low-compression, Otto-cycle, or explosion type, of engines, and that same volatility is wholly responsible for the high price of the gasoline. Such volatility in gasoline really means that a larger proportion of it evaporates at any given temperature level than in any other commercial derivative of crude petroleum. Ever since gasoline engines have been installed in trucks and busses and in other similar applications working for long periods at a time, the price differential has acted as a continuous inducement to modify the design so that less volatile and therefore less expensive fuel could be successfully utilized.

Most of these means to adapt the gasoline engines to operate on less volatile fuels such as kerosene, domestic heating fuel oil, etc., were based on adding heat to the fuel-air mixture in order to increase its vapor content and its ability to ignite readily by the timed spark plug without, however, the danger of pre-ignition from the heat of compression. Some of them use exhaust gases to heat the fuel-air mixture, with elaborate and bulky heat-exchangers incorporated in their design; others depend upon high velocity of the mixture in the intake header, which is surrounded by the

exhaust manifold; still others use a part of their fuel in heating the mixture or depend upon mechanical atomization of the fuel, etc. The Bureau of Engineering has tested a number of such devices during the years 1931-33 under many different names such as vaporizers, gasifiers, etc., but found them all, without exception, unable to meet the necessarily rigorous starting requirements. In other words the enthusiasm of the sponsors was found to be amply justified by the results of running tests in many of these devices, but they all eventually demonstrated their need for gasoline to be used in starting. The Bureau's attitude was consistently the same—either no gasoline at all and no fire hazard, or the simplicity of the conventional gasoline engine without any added "gadgets" which would save the fuel cost but would not reduce the danger of fire; since one gallon of gasoline in the boat presents potentially almost the same fire hazard as twenty gallons.

The fire hazard problem of gasoline is manifestly very acute in aviation also and receives much attention both by engine designers and oil companies. The introduction of the hydrogenation process, by means of which the hydrogen content of fuel and its vaporization characteristics can be controlled at will, gave the oil companies a way to produce the so-called *safety fuel,* a mixture of hydrocarbons with a narrow band of vaporization temperatures not exceeding the upper limit for gasoline. This fuel is safe at reasonably low temperatures because it does not readily vaporize at such temperatures. But it proved itself unsatisfactory as a reliable substitute for gasoline for starting purposes. Therefore attempted modifications in the design of the standard gasoline engine to use such fuel were abandoned and a solution sought in engines working on the Diesel or high-compression cycle.

Tests of Commercial Diesel Engines.

As early as July, 1929, two different commercially developed high speed Diesel engines were purchased and installed for a service test in 50-foot motor launches acting as ferryboats for the Engineering Experiment Station at Annapolis. This service proved to be exceptionally severe and much trouble was experienced with lubricating oil dilution which could easily be explained by the working schedule of these boats: (*a*) starting from cold, (*b*)

8-minute run in one direction, (*c*) 10–15-minute idling interval, (*d*) 8-minute return trip, (*e*) shutting down for 2–3 hours. One of these engines was eventually scrapped, principally because it became an orphan—its builder going out of business, while the other, after many modifications, earned its transfer to regular duty on one of the shore stations and was re-installed in one of the heavier boats there. These modifications consisted principally in a complete redesign of its fuel injection valve to permit no fuel to leak into the cylinder during starting or idling, when temperature differences between valve and cylinder head permitted excessive clearances and consequent leakage of fuel. However, this engine, No. 1 in Table 1, was much too heavy for use in a ship's boat and for various other reasons, not related to the merits of this particular engine, it was not available for adoption as the standard type for naval motorboats.

TABLE 1.

Commercial Diesel engines tested by the Navy and the Three Standard Navy Types—DA, DB and DC now adopted.

Engine No.	No. of cylinders	Bore and stroke	B.H.P.	R.P.M.		*Weight	Remarks
				Engine	Propeller		
		inches				Lbs.	
1	6	4½×6	50	850	850	2900	Installed in a shore station boat
2	6	5½×7	100	1200	600	3200	Selected for development
3	4	3×4½	20	2000	666	875	Installed in laboratory
4	6	4×5½	60	1700	700	1760	Selected for development
5	6	5×6	120	1500	615	3094	Installed in a shore station boat
6	4	3⅝×4½	25	1428	700	950	Selected for development
DA	4	3⅝×4½	25	1428	700	826	
DB	6	4×5½	60	1700	700	1760	
DC	6	5½×7	105	1190	700	2650	

*Complete with reverse and reduction gears, water and oil.

In the spring of 1932 the Bureau again canvassed all the high speed Diesel engine manufacturers of the country, with a view to obtaining their assistance in developing suitable types of Diesel engines to replace the existing types of gasoline engines. As a result, in May, 1932, another commercially developed engine of newly designed type was accepted for test at Annapolis, and later purchased by the Bureau—engine No. 2 in Table 1. This engine replaced its unsuccessful predecessor in the ferryboat service and proved to be very successful, generally speaking, and well-liked by the operating personnel. The only important objection to it was its weight.

Since it was desired to replace gasoline engines, it was important that both weight and overall dimensions be maintained substantially the same. On the other hand, it was quickly realized that the higher internal pressures of the Diesel engine would require heavier construction. An important decision was then reached, namely, that to compensate for the increased weight due to higher internal pressures a higher rotative speed (R.P.M.) of the engine and the inclusion of a reduction gear had to be accepted. However, this added complication will improve the efficiency of the propeller by lowering the propeller shaft speed to 600–700 R.P.M. for all three types of engines.

Following this decision, the Bureau, during the spring of 1933, purchased three additional commercially developed engines from three different makers, Engines Nos. 3, 4 and 5 of Table 1. The above mentioned five engines constituted all of the existing commercial high-speed marine Diesel engines of that day and only two of them were of the same manufacture. Realizing how important it was for the purposes of maintenance by the Navy to obtain all of the three required sizes of substantially the same type and design, the Bureau in the summer of 1933 addressed the following typical inquiry to the builders of the high speed Diesel engines:

"This Bureau is making a preliminary survey of possible sources of supply for high speed Diesel engines for motorboat propulsion. There are three types of gasoline engines at present in service which it is desired to replace by Diesel engines of similar size. To comply with weight restrictions imposed by the service requirements, it is assumed that all Diesel engines will be equipped with a reduction

gear, hence the propeller speed for all of the following three sizes is desired to be between 600 and 700 R.P.M.:

"(*a*) 20–25 horsepower size. Weight limit 750 pounds. Overall length not to exceed 53 inches.

"(*b*) 60–65 horsepower size. Weight limit 1800 pounds. Overall length not to exceed 78 inches.

"(*c*) 100–120 horsepower size. Weight limit 2300 pounds. Overall length not to exceed 95 inches.

" The above weight limits include reverse gear, reduction gear, starting motor and generator, lubricating oil and circulating water pumps driven by the engine, also a small bilge pump, clutch operated, as well as an exhaust header and water and oil in the engine. Storage battery and exhaust muffler are not included in the above weight."

Finally, as the result of considerable pressure on the part of the Bureau and with its cooperation, the manufacturer, who already had developed two of the desired sizes, successfully completed the smallest engine of his line, Engine No. 6 of Table 1, and one of these was acquired toward the end of 1933.

Meanwhile the laboratory facilities of the Experiment Station were augmented by the installation of a " cold room " and by an increase in competent personnel and the program of thoroughly testing the assembled engines proceeded throughout the summer and fall of 1933. It was early realized that, in addition to bringing the weight in line with the requirements of the Navy, the most difficult problem would be to insure reliable starting of the engines under winter temperatures prevailing, say in the New England states, leaving Alaskan waters as an exceptional service requiring special equipment. Thus it was required that engines with standard equipment must start normally at a temperature of ambient air and lubricating oil in the crankcase not exceeding 20 degrees F., and must be capable of being started with special equipment at temperatures as low as 20 degrees F. below zero. The European solutions of this problem permitting circulation of hot water through the engine jackets, or priming by gasoline were not considered satisfactory for the conditions prevailing in U. S. Navy. As a result special high torque starting motors and switches, and storage bat-

teries of high discharge rate with reasonable weight were developed; also electric heating of induction air was introduced.

Thus the year of 1934 found the Bureau fully prepared to comply with the spirit of the National Industrial Recovery Act, approved 16 June, 1933 (familiarly known as NIRA)—" To return the maximum number of men to gainful employment without delay "—and concurrently to meet the necessary delivery dates for the motorboats required for the vessels contracted for under the same act. All the details for the three sizes of Diesel engines required to propel these motorboats were developed and, with the funds made available by NIRA, the Bureau, on 3 January, 1934, entered into a contract with The Buda Company (the American licensee of the M.A.N. Company of Augsburg, Germany) to supply a total of 158 Diesel engines—108 of 25-horsepower size, 22 of 60-horsepower size, and 28 of 105 horsepower size; these engines to comply with Bureau specifications somewhat modifying the original designs of the manufacturer as shown in Engines Nos. 6, 4 and 2 of Table 1. Manufacturing rights to permit reproduction of these engines by the Norfolk Navy Yard were likewise purchased, and that yard was authorized to make ready for manufacturing the three selected sizes of Diesel engines in order to replace, eventually, all existing gasoline engines in power boats. Thus ended the development of the Navy standard motorboat Diesel engines, the design of which will now be described in detail.

NAVY STANDARD MOTORBOAT DIESEL ENGINES.

The Diesel Cycle.

Truly great principles can be reduced to an exceedingly simple formula or conception. Thus it will long be remembered that Dr. Rudolf Diesel, a German refrigeration engineer, proposed to use the heat of compression to ignite the fuel charge in an internal combustion engine and thereby originated the engine bearing his name. At a time when ignition of the fuel charge was being effected by an open flame sucked into the cylinder, by porcelain tubes heated from an outside source or by low-tension magnetos with make-and-break igniters, Diesel's idea was revolutionary indeed.

The following characteristics of the new cycle came about mainly as consequences of the above principle or followed the trend of the art at that time: (*a*) compression of air only required, (*b*) fuel injected into the air thus heated by compression at or near the dead center, (*c*) liquid fuel became the principal type used (Diesel himself experimented originally with powdered coal and several experimental engines of this type are reported to be successfully operating at present; also in certain American oil fields compressed natural gas is being successfully used on a considerable scale as fuel in Diesel engines), (*d*) high pressure air to inject, distribute and atomize the fuel charge was the original method of fuel injection and continued to be so as long as the status of the art required it, and (*e*) metering of liquid fuel by permitting the suction valve to seat only as long as it was necessary to discharge the metered quantity was a temporary concession of the designer to the status of the art.

Diesel's ambition, which cost him his fortune and led to his untimely death, was to create a small high-speed engine for motorboat propulsion. But real progress toward the successful solution of this problem was impossible as long as only one man or even one organization was trying to solve the multitude of problems involved. It is only when the volume of prospective business became sufficiently large to attract many specially qualified men and organizations that sure steps toward success were taken. The Bureau's own unsuccessful efforts in 1923, 13 years after Dr. Diesel's death, to solve the motorboat problem without the use of the present day higher speeds and mechanical injection of fuel are an additional proof of the great difficulties involved. It is only when the late unlamented " depression " released so much engineering talent, which normally was otherwise employed, to search for new worlds to conquer, and when the problem of fuel economy was brought to the fore by the wave of road-building and construction, requiring thousands of tractors, and by the long-distance hauling of goods in trucks and passengers in buses, that the great American automotive industry was forced to interest itself in the application of the Diesel cycle to high-speed engines. Then it became possible to assemble the men and funds required to produce the successful motorboat Diesel engine.

Description of Engines.

As finally developed, it is of the multi-cylinder, four-cycle, high-speed geared type, with electric starting and with mechanical injection of fuel, differing but little from the conventional automotive gasoline engine. General views of engines as developed and built are shown by Figures 1 to 6 inclusive. Certain special features wherein the engines differ somewhat from conventional designs are described in detail under the following headings:

The Fuel Injection Pump.

The first motorboat Diesel engine—No. 1 of Table 1—to pass the tests—used a low pressure fuel metering pump and a simplified system of air injection of fuel with a small plunger of the injection air compressor in the fuel valve itself. This system is successfully used by this particular engine builder in hundreds of trucks on the roads today. However, the majority of high-speed Diesel engine designers adopted the Bosch fuel pump, developed by the German manufacturer of magnetos and other specialties for gasoline engines, and, originally, the engines Nos. 2, 4, 5 and 6 in Table 1 were also equipped with this pump. To comply with the requirements of the depression legislation that only domestic products be used, an American manufacturer, the Ex-Cell-O Aircraft & Tool Corporation of Detroit, was encouraged to develop a fuel injection pump, which after exhaustive tests on the finally selected types of engines was adopted as standard equipment for the Navy standard motorboat Diesel engines.

The fuel injection pump assembly is in reality a combination assembly including the injection pump, governor, fuel filter and transfer pump. The governor, fuel filter, and transfer pump are each complete units in themselves incorporated as integral parts of the injection pump assembly. The injection pump proper consists of two major component parts, the driving unit and the hydraulic unit.

Figure 7 shows a sectional view through the four-cylinder pump. Except for the number of plungers, the sectional view of the six-cylinder pump is identical. The driving unit consists of the pump body casting in which the mechanical parts required to operate the

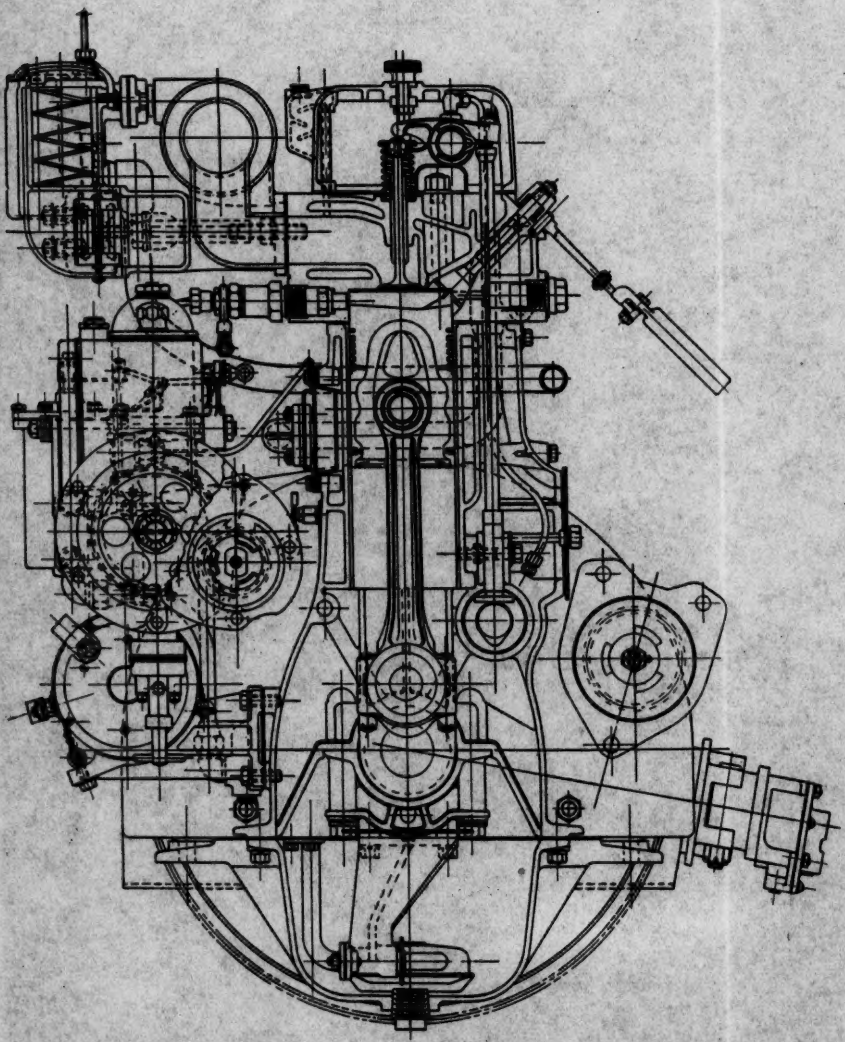


FIGURE 1.—TYPE DA SECTIONAL END VIEW.

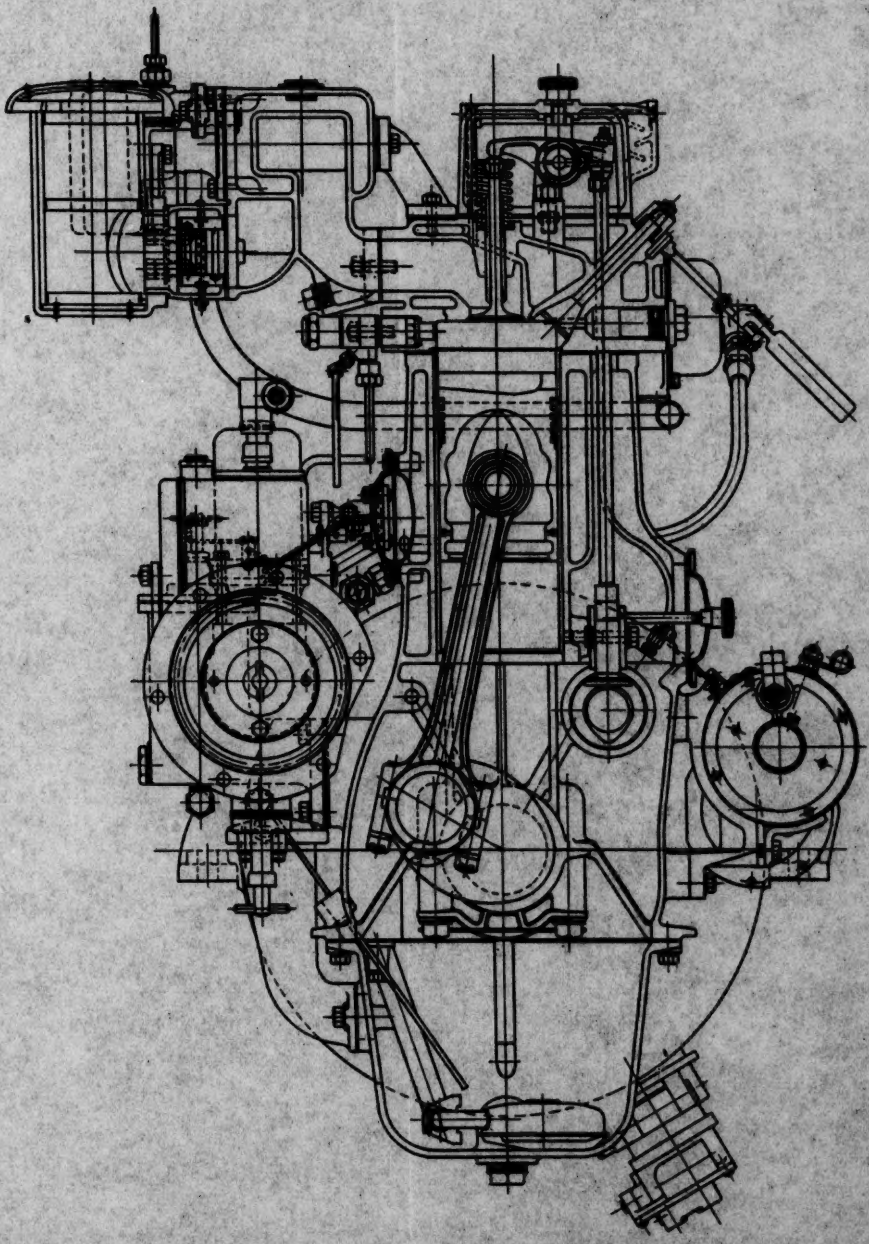


FIGURE 3.—TYPE DB SECTIONAL END VIEW.

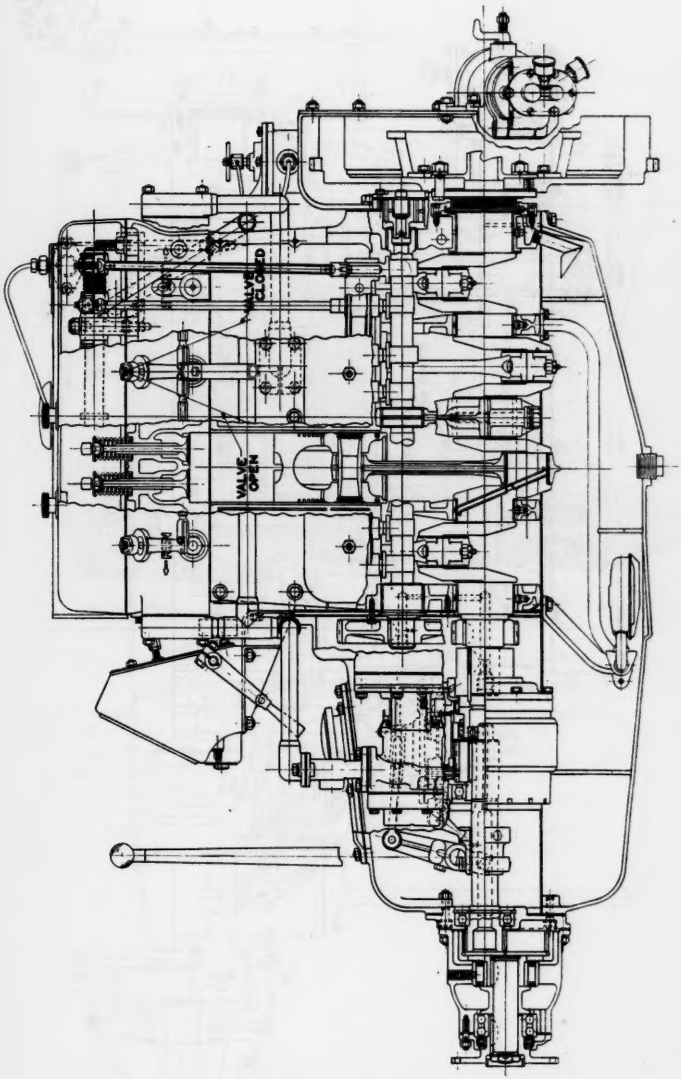


FIGURE 2.—TYPE DA SECTIONAL SIDE VIEW.

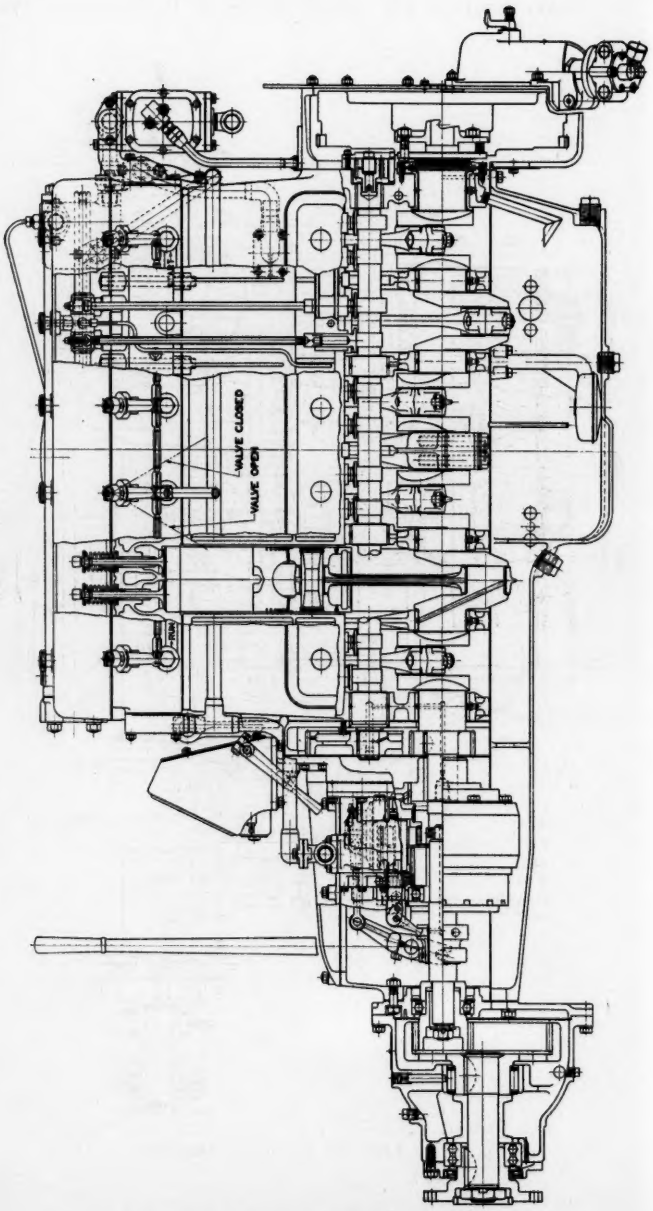


FIGURE 4.—TYPE DB SECTIONAL SIDE VIEW.

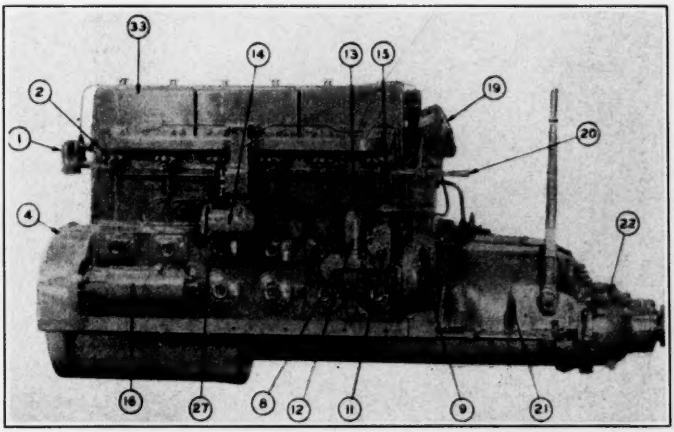


FIGURE 5.—TYPE DC DIESEL MARINE ENGINE.

NOMENCLATURE OF PARTS—FUEL PUMP SIDE.

1. Thermostat Housing.
2. Fuel Injection Nozzles.
4. Engine Name Plate.
8. Fuel Injection Pump.
9. Fuel Pump Timing Plug.
11. Fuel Pump Governor.
12. Fuel Pump Filter.
13. Fuel Pump Filter Vent Plug.
14. Air Silencer.
15. Tachometer Drive Adaptor.
18. Electric Starting Motor.
19. Instrument Panel.
20. Throttle Control Lever.
21. Reverse Gear.
22. Reduction Gear.
27. Valve Push Rod Covers.
33. Cylinder Head Covers.

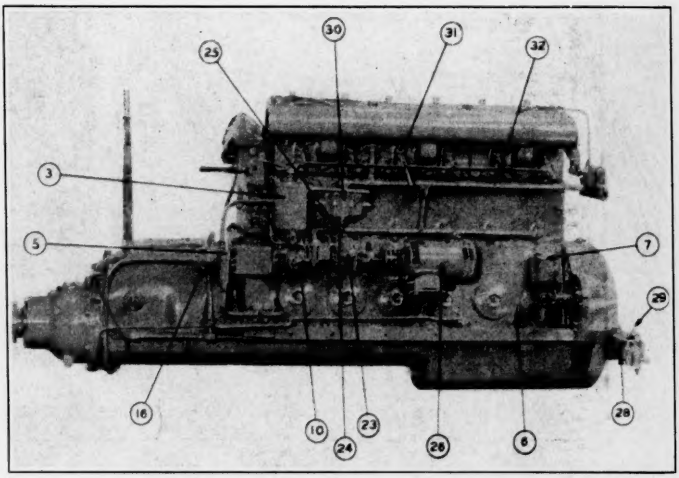
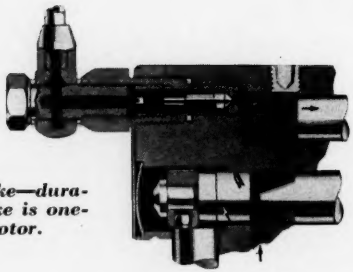


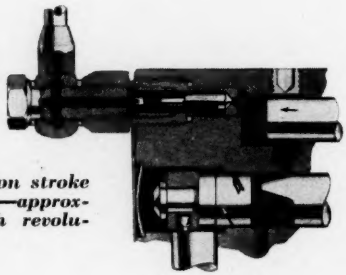
FIGURE 6.—TYPE DC DIESEL MARINE ENGINE.

NOMENCLATURE OF PARTS—WATER PUMP SIDE.

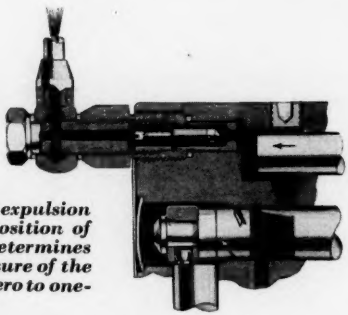
3. Lubricating Oil Filter.
5. Oil Pump Primer Plug.
6. Oil Level Gauge.
7. Oil Filler Cap.
10. Fuel Transfer Pump.
16. Oil Pressure and Scavenger Pump.
23. Water Pump.
24. Water Pump Drain Cock.
25. Water Inlet Connection.
26. Electric Generator.
28. Bilge Water Pump.
29. Bilge Water Pump Operating Handle.
30. Oil Cooler.
31. After Chamber Valves.
32. After Chamber Plugs.



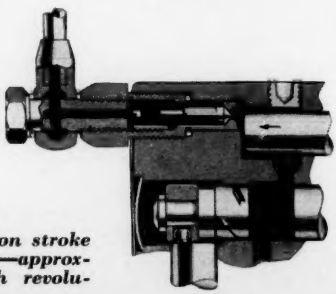
1. *End of filling stroke—duration of filling stroke is one-half revolution of rotor.*



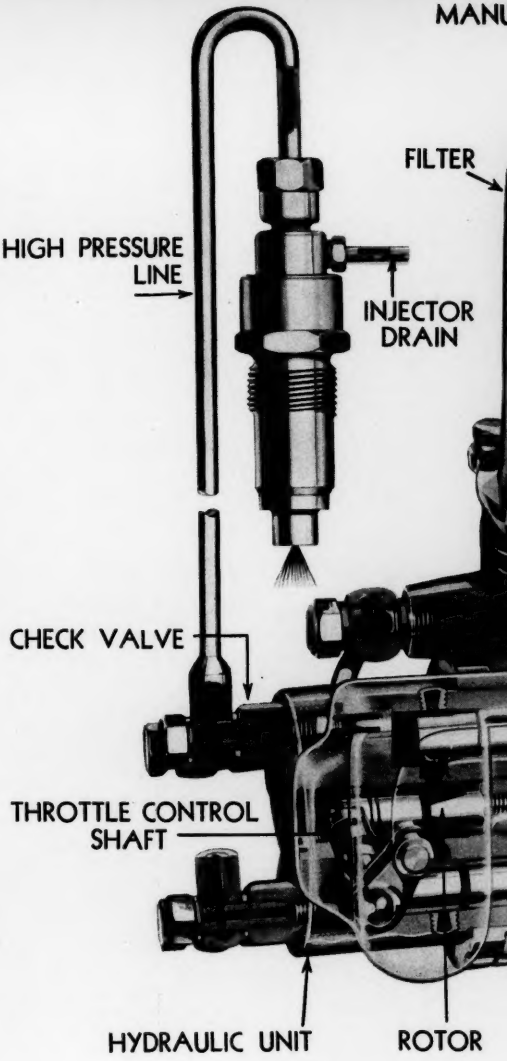
2. *Portion of expulsion stroke preceding injection—approximately one-fourth revolution of rotor.*



3. *Delivery portion of expulsion stroke—the axial position of the rotary valve, determines the duration of closure of the by-pass port from zero to one-tenth revolution.*



4. *Portion of expulsion stroke following injection—approximately one-fourth revolution of rotor.*



HYDRAULIC UNIT DRA

Lubrication Oil

High Pressure Fuel Oil

Low Pressure Fuel Oil

Brass and Bronze Parts.

FIG. 7.

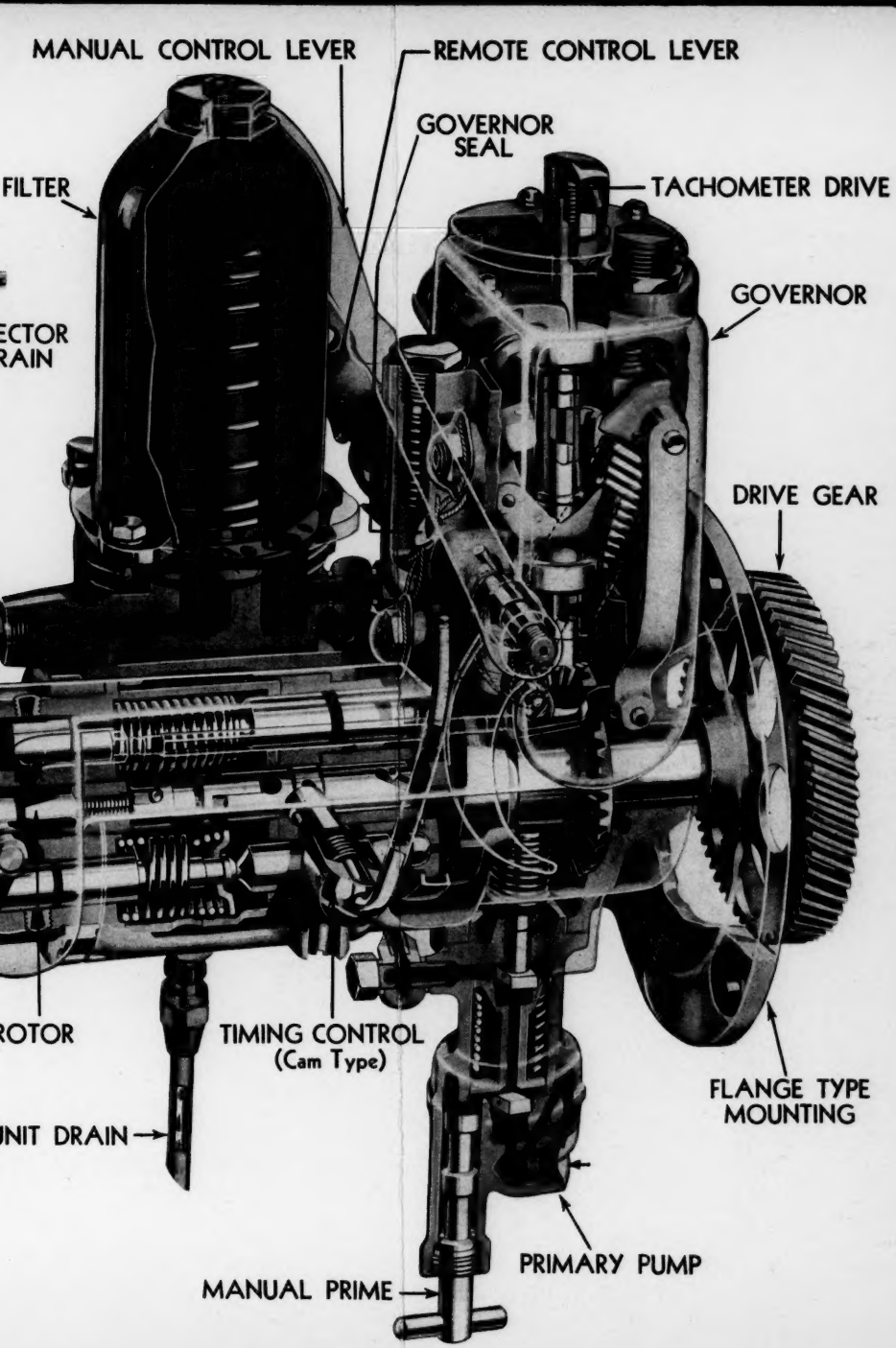


FIG. 7. FUEL INJECTION PUMP

pump plungers and the timing control mechanism are assembled. The rotary motion of the drive shaft is converted into the reciprocating motion of the tappets, which in turn operate the pump plungers through the medium of an angular swash plate. The degree of the angle governs the length of the stroke of the plungers.

The tappets are equally spaced in a cylindrical tappet body, parallel to each other and to the central drive shaft. Each tappet operates a pump plunger, one for each engine cylinder. The opposite rounded ends of the tappets fit into sockets contained in a shoe plate which bears against the angular face of the swash plate. The swash plate is equipped with a beveled gear for driving the governor, and also with an eccentric for operating the fuel transfer pump.

The timing control feature permits a variation of the time when injection occurs by advancing or retarding the rotary valve. This is accomplished by means of an eccentric on the timing control shaft which transmits endwise spiral motion to the end of the drive shaft, which drives the rotary valve. This is connected to the fuel throttle valve by means of a lever and cam. Details of the governor, fuel filter and transfer pump present no features of particular interest and may be studied from the illustration.

All of the precision parts of the injection system such as pump plungers, rotary valve, together with their springs and retainers, etc., are assembled and sealed in the hydraulic unit. The plungers are located in lapped bores in the stator and are operated by the tappets. In the center of this unit is a central rotary valve which is driven by an offset tang on the drive shaft, and controls both the quantity and the time of the injection fuel. The action of the control valve is shown schematically by Figure 8. It is important to note that there is only one valve to control the metering of fuel—a feature which is believed to assure equal distribution of load between the cylinders with consequent freedom from the effects of overloading.

By-pass holes extend radially from each plunger cavity to a fuel supply chamber which surrounds the central rotary valve. A land on the valve, triangular in shape, seals these by-pass holes

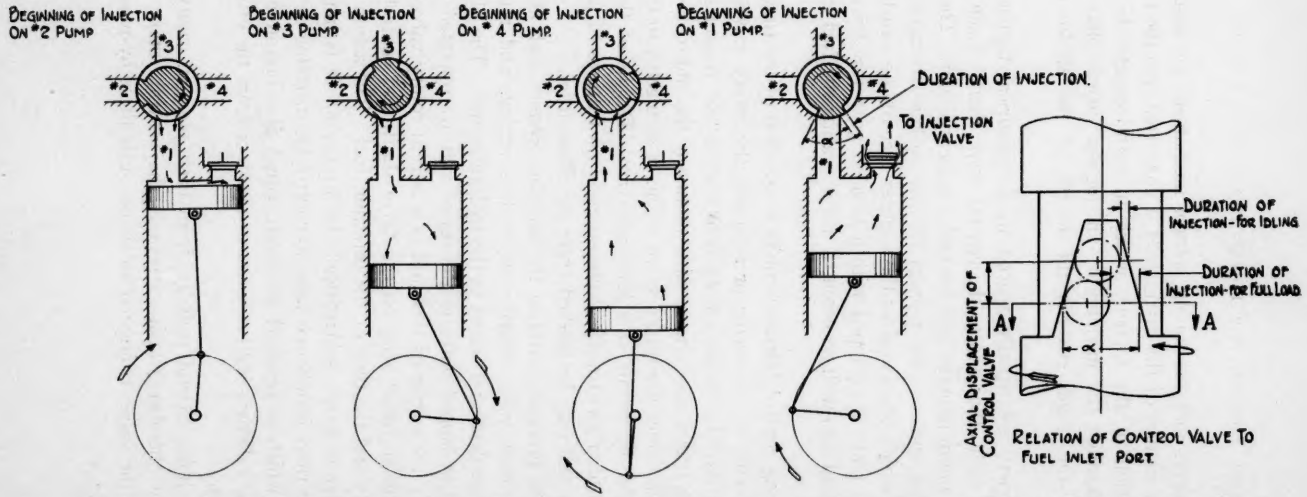


FIGURE 8.—DIAGRAM SHOWING SCHEMATICALLY THE ACTION OF THE CONTROL VALVE OF THE FOUR CYLINDER EXCELLO FUEL INJECTION PUMP.

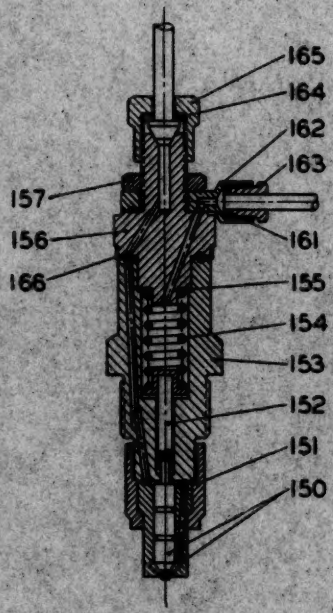


FIGURE 9.—TYPE DA INJECTION NOZZLE.

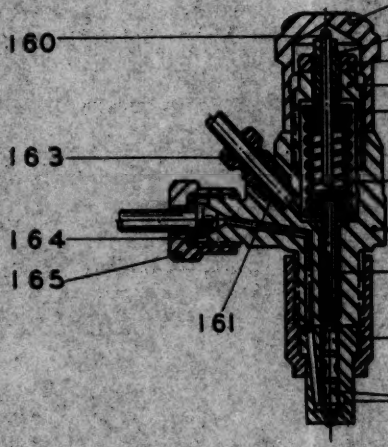
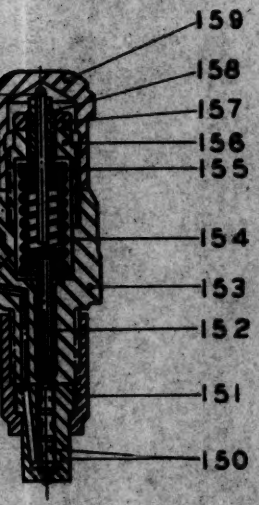


FIGURE 10.—TYPE DB INJECTION

	DESCRIPTION
150.	Nozzle body with valve.
151.	Nozzle cap nut.
152.	Spindle with lower spring seat.
153.	Holder body.
154.	Pressure adjusting spring.
155.	Adjusting washers.
156.	Spring retaining cap nut.
157.	Leak-off connection securing nut.
158.	Pressure adjusting screw.
159.	Protection cover.



Injection Nozzle.

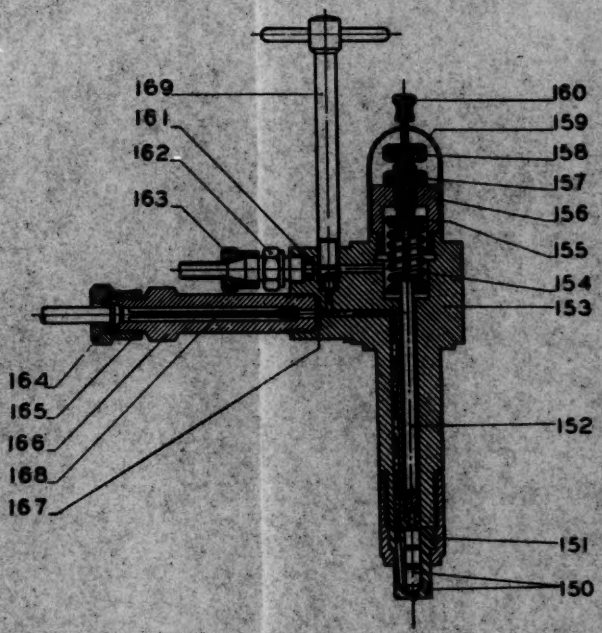


Figure 11.—Type DC Injection Nozzle.

ESCRIPTION OF PARTS.

eat.

g nut.

160. Feeler pin.
161. Gasket for leak-off.
163. Leak-off stud.
163. Leak-off nipple nut.
164. Washer for fuel inlet nipple nut.
166. Fuel inlet nipple nut
166A. Fuel inlet stud with edge filter.
167. Gasket for fuel inlet stud.
168. Edge filter in fuel inlet stud.
169. Bleeder screw.

during a portion of the expulsion stroke of the associated plunger. While this hole is closed, the fuel is discharged through a check valve into the lines and to the nozzle. The length of the closed period is varied by varying the endwise motion of the rotary valve. The narrowest portion of the land is not of sufficient width to entirely close the by-pass hole, therefore no injection occurs. This is the stop position. By shifting the rotary valve endwise, a wider portion of the land seals off the by-pass, and injection occurs, variable in duration and quantity by the endwise shift of the valve.

A small percentage of the fuel under high pressure will leak past the plunger and central rotary valve. This fuel leakage drains by gravity from the drain connection on the drive housing.

Fuel Injection Nozzles.

The fuel is drawn from the main supply tank through the main fuel filter of the self-cleaning metal-edge type by a transfer pump and delivered under approximately 25 pounds pressure to the filter mounted on the injection pump where it passes through the cloth and metal-edge elements to the supply chamber, in the hydraulic unit. It enters the plunger cavities through a central rotary valve. The plungers force the fuel through check valves, into the lines and to the injection nozzles from where it is injected into the cylinder combustion chambers.

The fuel injection nozzles are of the closed pintle type (see Figures 9, 10 and 11). They are cleaned automatically during the process of injection and only in case of a very dirty fuel being used, will it be found necessary to remove a nozzle for cleaning.

Fuel is fed to the inlet connection (165), through drilled passages to the nozzle body and valve (150). The nozzle valve is kept on its seat by the valve spring (154) and the spindle (152). This spring is adjusted at the factory to hold the valve on its seat until a pressure of 2000 pounds is delivered, which raises the valve off its seat to allow injection.

Combustion Chambers.

Cylinder heads are of the overhead valve type. Valves are operated by the conventional push rod and rocker arm mechanism.

Combustion chambers are of the "After Chamber" type, *i.e.*,

attached to the main combustion chamber is an auxiliary chamber or pocket connected to the former by a small hole. This feature causes high turbulence, clean and smooth combustion and improved engine performance.

After chamber valves are provided as a means of sealing off the " after chambers," thereby increasing compression to facilitate starting, see Figures 1 and 3. The valves are installed from the combustion chamber side, with the stems extending through the outer side of the cylinder heads. The valve heads are cone-shaped and drilled to form an open passage to the "after chambers " when the valves are in the running positions. Rotating the valves by means of the levers and linked rods closes this passage. The levers are keyed to the taper end of the valve stems and held in place by a slotted nut. A valve spring is installed between each lever and the cylinder head to hold the valve on its seat.

Electrical System.

The electrical system consists of a generator with its control unit or cut-out relay, a starting motor with its magnetic and hand-operated switches and the storage battery. The hand-operated switch has two notches. On the first notch the Bendix pinion is permitted to mesh with the flywheel gear and when the second notch is at ON the magnetic switch operates the cranking.

An air preheater installed in the inlet air passage consists of an electric heater grid connected directly across the battery terminals by means of a contact maker. In cold weather to assure reliable starting the current is turned on for about 30 seconds prior to cranking and thoroughly heats the grid through which the inlet air passes.

Cooling and Lubricating Oil Systems.

The engines are salt water cooled. Positive water circulation is provided by a double gear type water pump which forces part of the water through a distributing header in the cylinder head casting across each cylinder head and into the exhaust header, while the other part is first forced around the individual cylinders and then joins the first stream before it goes to the thermostat and either

overboard direct or through the oil cooler. When the engine is cold the thermostat permits the water to flow from the pump directly overboard without circulating through the engine water jackets and only gradually admits more and more cold water into the engine system.

All parts of the engine are force-feed lubricated. The oil is drawn from the sump by the pump through a suction screen and delivered to a drilled passage in the crankcase protected by a relief valve, which returns excess oil to the sump. The oil stream then passes through a filter of the self-cleaning metal-edge type to the main gallery line in the crankcase, from which branches lead to main and cam shaft bearings, oil pressure gage, and idler gear. The crank pin and wrist pin bearings are lubricated in the customary manner through the drilled crankshaft and connecting rod while oil leads from the cam shaft bearings supply lubrication to rocker arms and valve gear.

The reverse gear receives its oil through a drilled passage in the end of the crankshaft, the excess oil draining back to the sump, while the reduction gear is oiled by an external pressure lead.

Reverse and Reduction Gears.

The reverse gear used is of the double clutch planetary gear type. In the forward position the entire gear drum is locked tightly to the engine crankshaft, revolves as a single unit and drives on clutches only. All the vibratory back-lash is eliminated through the split cone clutch which not only serves as a power clutch but also contracts and rigidly grips the serrations on the engine sleeve, and centers the revolving parts. The clutch drum may thus act as a vibration damper, assisting the smooth running of the engine.

The forward drive is through a double friction clutch. The forward clutch is of the split cone type which has serrations on inside, which are a sliding fit over the serrations on the engine sleeve. When it is forced into its case, it rigidly grips the engine sleeves and revolves the drum or case. The propeller shaft is connected to the case by a second clutch, which consists of a series of friction discs. These discs are mortised alternately into the propeller drive sleeve gear and the case or drum.

When the clutch lever is thrown forward, the toggles force home the plungers clamping all the friction surfaces together, locking all moving parts so that the whole device functions as a solid coupling between the motor and the propeller shaft.

The reverse drive is obtained by throwing the lever clear back, which releases the forward drive and engages the brake band on the outside of the case by means of a cam toggle. Thus in the reverse direction the drive is through gearing at 80 to 88 per cent of the engine speed.

To run in a neutral position, the lever is thrown midway between forward and reverse, which releases both the reverse and forward drives, and permits the gearing to run idle.

The reduction gear is very simple. An overhung external gear is mounted on the reverse gear stub shaft and meshes with an internal gear on the reduction gear shaft. The tail shaft is supported by two bearings. At the propeller shaft end is a double row ball thrust bearing which will take the propeller thrust while the forward end is supported by a roller bearing.

ELASTIC MOUNTING OF DIESEL ENGINES.

With the introduction of Diesel engines it was desired to take advantage of the advances made in the automotive field in mounting engines and in transmitting their power without shocks or vibration. For that purpose the original engines were mounted on rubber vibration dampers and in place of the universal joint or the flexible coupling of the past a rubber-mounted elastic coupling was installed between the engine and the propeller shaft.

The rubber vibration dampers consist of three steel sections, one channel and two angles, held together by rubber vulcanized between them—see Figure 12. The engine weight rests upon the central channel section, while the angles are riveted to a strip bolted to the engine girders of the boat. As a result the engine is permitted to vibrate freely without, however, transmitting its vibration to the hull.

The elastic coupling—see Figure 13—consists of a hub on the propeller shaft with four or six radially disposed driving pins, on which are mounted round rubber trunnion blocks. The torque is

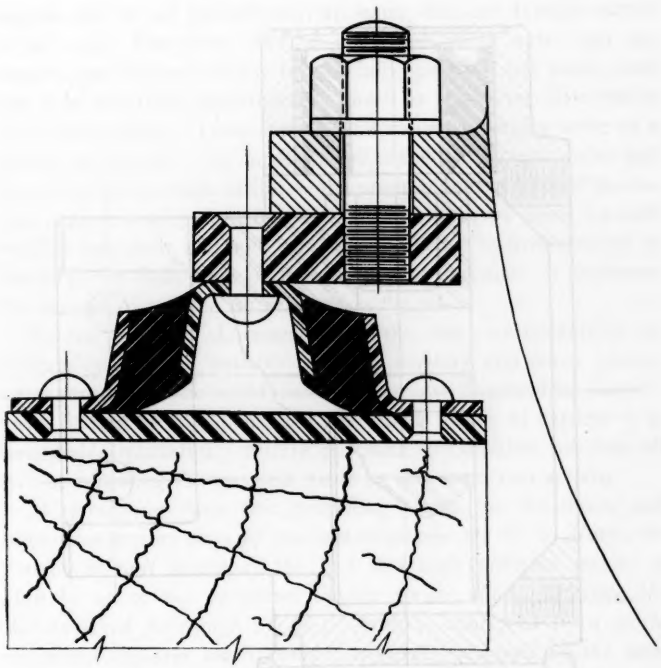


FIGURE 12.—ELASTIC ENGINE MOUNTING.

transmitted by the split flange, bolted to the coupling flange of the reduction gear, to the rubber trunnions, and through them to the propeller shaft. The coupling requires no lubrication, has no back lash and, therefore, develops no noise, permits considerable misalignment and is completely enclosed.

Both elastic coupling and rubber vibration dampers have been thoroughly tested out under most severe conditions and are expected to meet successfully all requirements of the service.

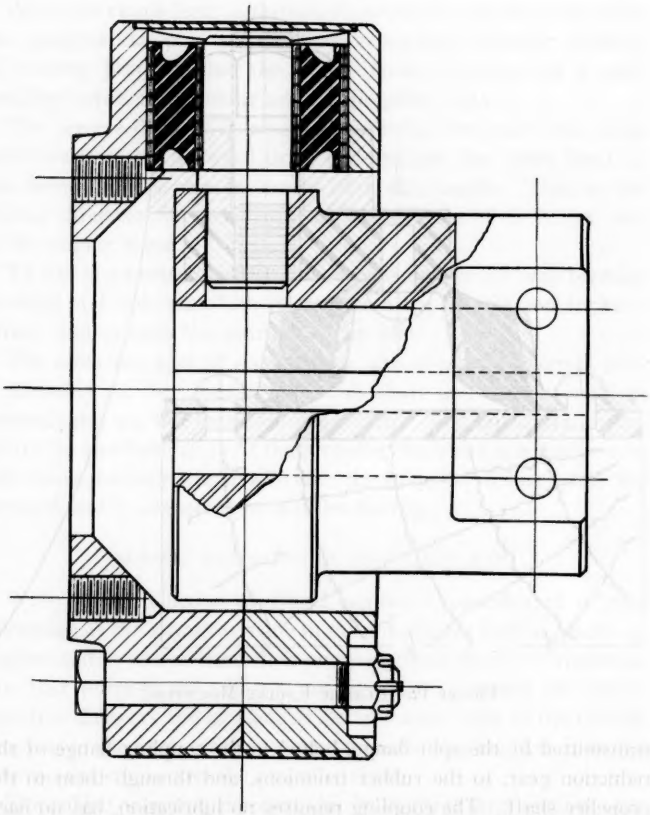


FIGURE 13.—ELASTIC COUPLING TO PROPELLER SHAFT.

DIESEL FUEL REQUIREMENTS.

The ships of the new construction program will receive in addition to Dieselized motorboats also Diesel driven emergency generators and to accommodate both of these types of engines a fuel distributing system, which includes the necessary tanks and centrifugal purifiers, has been installed. The minute orifices in the fuel injection nozzles and the carefully lapped plungers of the injection pump

require, first of all, protection from water, dirt and foreign matter in the fuel. Therefore, fuel oil requires that its water and ash content, and carbon residue be carefully specified and tested, and that it be carefully centrifuged before it is stored for distribution to the motorboats. Three different filters on the engine serve as a further protection. The small orifices to the pump require also that the oil be fluid enough to follow the pump plungers without cavitation, hence viscosity must be specified as well as pour point for cold weather operation, and both carefully checked. To insure safety in handling, the flash point of the oil must be specified—it expresses the amount of volatile constituents in the oil.

But the principal characteristic of the fuel—its ignitability or ignition quality still remains largely a mystery and many laboratories throughout the world, including our own Engineering Experiment Station at Annapolis, are developing means to express it in measurable quantities. Future purchase specification for fuel oil will be reflecting the progress made by this important activity.

In sponsoring these new propelling plants for the severe and arduous everyday duty of the motorboats in the U. S. Navy, the Bureau is well aware of the fact that their ultimate success is entirely up to the personnel of the forces afloat. Despite the distinguished parentage of these engines—conceived by a world renowned engineer and inventor, originally designed by the most outstanding engineering organization in this field in the world today, adapted to American production methods by a builder of millions of horsepower in internal combustion engines for marine and automotive use—despite all the tests to which the Bureau has subjected these engines and which were meant not only to simulate service conditions but aggravate them in order to discover possible weaknesses, these new engines must face the difficulties of all new things, and can succeed only with the sympathetic understanding, good will and sincere efforts of every individual "gob" who will have to push the starting button. The forbearing cooperation of the personnel afloat is, therefore, absolutely essential during the trying first stages in order that the many outstanding advantages of these engines may be realized to the full for the U. S. Navy.

NOTES.

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NAVAL INTEREST IN HIGH SPEED.
Journal de la Marine Marchande, 17 October, 1935.

OUR NEXT BATTLESHIPS—THE NEED FOR SPEED.
Journal of Royal United Service Institution, November, 1935.

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Motorship, November, 1935.

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Marine Journal, 15 December, 1935.

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Marine Journal, 15 December, 1935.

SOME FACTORS IN NAVAL LIMITATION.
Shipbuilding and Shipping Record, 5 December, 1935.

PETROLEUM SHORTAGE AND ITS ALLEVIATION.

By L. C. SNIDER[1] AND B. T. BROOKS.[2]

In a report made last year, to a sub-committee of Congress, the United States Geological Survey stated:[3]

"It should be urged that making provision in advance against the day, certainly not long distant, when waning domestic petroleum reserves will fall shorter and still shorter of meeting American domestic needs, is not only natural and logical—it is fundamentally sound and necessary."

The problem as to whether or not the United States can produce enough petroleum to supply its own consumptive demand at any assumed demand rate and under any assumed price structure lies principally with the field of the geologist. The demand and price structure will depend on the methods of utilization and on the degree to which other substances may be substituted, at higher price levels, for petroleum and its products. The alleviation of a petroleum shortage presents a series of problems of better utilization and the development of substitutes, the successful solution of which depends almost entirely on the efforts of chemical engineers.

In 1912 the fear that the rapidly increasing demand for motor fuel would soon exceed the amount of gasoline available in crude petroleum led directly to the processes for cracking fuel and gas oils to gasoline. The ensuing technical developments and the improved economic position of the industry resulting would be hard to overestimate. A single company capitalized its cracking patents at $100,000,000. The petroleum, coal and chemical industries are far better equipped, by a more numerous, scientifically trained personnel, to cope with the inevitable changes than the petroleum industry was in 1912. In many respects history will probably be repeated.

It is by no means premature to consider the possibility of a petroleum shortage in the United States, to consider what has already been done by chemical engineers and researchers to produce petroleum-like products from other sources, and to consider what changes are likely to occur in the petroleum industry and in the utilization of petroleum products.

There never has been any question but that some time our petroleum supply would approach exhaustion. But long before the extreme condition of *exhaustion* is reached we shall experience a *shortage* of petroleum. The essence of the question is *when* a shortage will be reached. We believe that there are now sufficient facts to give a reasonable answer to that question. There is abundant evidence that we may expect a shortage of petroleum sufficient to necessitate a marked increase in our imports and an increase in the petroleum price structure within five to eight years.

Dependence upon imports for a substantial part of our petroleum requirement would, in the event of war, make the nation dependent upon the navy to protect these imports, the failure of which would cause a serious dislocation of industry.

Five to eight years is indeed a short time in which to develop to efficient large scale operation any very new process of major importance. The ammonia-soda process was first patented in 1838, but was not commercially successful until 1872. The successful development of viscose took nearly as long a time. Bergius began his work on the high pressure hydrogenation of coal in 1913 and Franz Fischer started his work on hydrogenation in 1914.

[1] Geologist, The Cities Service Company, 60 Wall Street, New York, N. Y.

[2] Chemical Engineer, 114 East 32nd Street, New York, N. Y.

[3] Petroleum Investigations: Hearings before Sub-committee on Interstate and Foreign Commerce, 73d Congress, Washington, 1934, p. 892.

It is fortunate that work on these processes was undertaken at such an early date and has been brought to a stage which assures their being important factors in alleviating a future petroleum shortage. In view of the time which must elapse before these processes, or the distillation of oil shale, can be further improved and installed on a scale big enough to produce a large proportion of our present oil requirement, the presentation of facts bearing upon the probability of a shortage of petroleum in the United States in a few years should be of general interest.

It required forty-four years of the American Petroleum Industry, from 1857 to 1900, to produce the first one billion barrels of petroleum from American fields. We now consume this amount in from thirteen to fourteen months.

During the World War we had gasless Sundays due to the unusual demands of war, although aviation and the mechanization of field artillery and army transport had not been carried as far as has been done since. The navies of the world now operate almost entirely on fuel oil.

Just ten years ago last December, President Coolidge appointed the Federal Oil Conservation Board. The fear for our future oil supplies which actuated the appointment of this Board has largely been dissipated during the intervening ten years by the discovery of a series of new producing fields of record-breaking magnitude. It is also a fact that every estimate of our total possible future production of crude petroleum, in the United States, made by qualified authorities up to the year 1925, has been exceeded by actual production, in addition to which we have a known future reserve of ten to twelve billion barrels. These estimates were as follows:

TABLE I.

Year	Authority	Estimated Reserve (billion bbls.)	Interim Production (billion bbls.)
1914	Ralph Arnold	5.7	13.7
1915	U. S. Geological Survey	7.6	13.3
1918	David White	6.7	12.5
1921	Geologists of A. A. P. G.	9.15	11.3
1925	Comm. of Eleven A. P. I.[4]	5.3	8.88

The facts have tended to discredit the professional opinions of petroleum geologists and have created an entirely unfounded and unscientific, widespread belief that oil would continue to be "found" in abundance in the United States. However, many more facts are known today than when the earlier estimates were made. The earlier estimates were made prior to the development of the technique of deep drilling and could not include oil possibly existing beyond the reach of the drilling methods of those years. Today, with wells down to 12,000 feet, drilling in all but a few localities has been carried to the lowest possible producing strata and in many cases to the bottom of the sedimentary rocks. The very rapid rate of discovery of new pools in the years 1925-30 was due chiefly to the rapid application of deep well technique, to the more rapid drilling and exploitation of fields when discovered, and to the rapid increase in the application of geological study and geophysical methods of locating favorable structures which was particularly marked after 1920.

The statement of our reserves in terms of years' supply, such as ten or twelve years, is highly misleading as indicating that no concern need be

[4] An estimate based upon producing and proved acreage. No estimate was made for unproven territory.

felt until near the end of that period, whereas we shall need a new supply of considerable magnitude in about five years, no matter whether our proven reserves are *equivalent* to ten or fifteen years' supply. Though we may experience a *shortage* or an inadequate supply in five to eight years, we shall certainly not see *exhaustion* of our oil fields in fifty years. This error, in stating our reserve in terms of years' supply, is so common that it is perhaps worth while to point out that the profitably productive life of an oil field may be fifty years, or more, as in the case of Pennsylvania, New York, and Ohio. New York attained its peak production in its initial year, 1882, and in 1933 was still yielding about 0.3 per cent of our domestic production. The same thing is shown in another way, *i.e.*, less than two per cent of the wells produce fifty per cent of our oil, the two per cent being wells in recently discovered fields.[5] The oldest fields are still yielding small quantities of oil (see Figure 1). Though our known reserve may be *equivalent* to twelve years' consumption, there is no method now known by which this oil can be brought above ground in twelve years, no matter what its value.

In all probability the first result of an increasing shortage of domestic crude petroleum will be the importation of oil from South America and possibly other fields. Though oil is now produced in some South American fields at a relatively low cost, one need only recall the history of Chilean nitrate to realize that the economic needs, or caprice, of the South American republics may be a factor when we really need oil from this source. The known reserves in Venezuela have been estimated to be about equal to the reserves in California.

Following a period of increasing petroleum imports and increasingly high price levels for crude and all petroleum products a point will be reached when certain substitutes will *begin* to compete and check the rising price of petroleum. The most promising of such substitutes are shale oil, oil made by high pressure hydrogenation of coal, and oil made by the reduction of water gas. Each of these processes can produce motor fuel and lubricants in quantities sufficient to meet our present petroleum requirement for many years, but only at substantially higher price levels. It will be remembered that in 1921 the base price of gasoline, f.o.b. mid-continent refineries, was 14 cents per gallon, which is only slightly below the cost of producing motor fuel from coal. Their present status is considered in the following pages.

Exports, particularly of manufactured (refined) products, are generally considered a legitimate part of any business. If exports are included in the total demand we find that the domestic supply of crude petroleum in the United States has been insufficient to meet the total demand for twenty years, with one exception, and that the deficiency has been made up by imports. During the last nine years the net deficiency has been more than 500,000,000 barrels. (From statistics compiled by the U. S. Bureau of Mines.)

Assuming that exports may be eliminated and considering our domestic requirement only, there is a real and imminent danger that our domestic supply of petroleum will be less than our consumption on a price basis similar to the present one. By imminent is meant a period of about five to eight years.

The evidence for this conclusion cannot be briefly stated. The possibilities of keeping up our present rate of production from fields now known, by the discovery of new fields, by deeper drilling, and by recovery of oil left in the ground after flowing and pumping, are considered.

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[5] Petroleum Facts and Figures, published by the Am. Petroleum Inst., New York, Ed. 2, 1929, p. 93.

According to Wallace Pratt, the known reserves of petroleum, producible by known methods, are located as follows:

Oklahoma	1,000,000,000 barrels
California	3,500,000,000 barrels
Texas	3,500,000,000 barrels
All others	2,000,000,000 barrels

According to V. R. Garfias[6] and the U. S. Geological Survey[7] our proven petroleum reserves may be as much as 13 billion barrels. A study, recently made by a well known investment company of the oil reserves held by all important producing companies, gives us a total proven reserve of 12 billion barrels. If we are not to deplete our present known reserve, it will require the discovery of about one billion barrels of new oil each year. Over the last four years, our estimated average rate of discovery has been only five hundred and eighty million barrels per year, and the recovery of part of this depends on prices being higher than at present.

It has been pointed out recently by Wallace Pratt[8] that "the rate of discovery curve climbs gradually to a conspicuous maximum in the period 1926-1930 and then slumps off sharply to a point lower than it has been for nearly twenty years. * * * The slump following 1930 is a reflection of the failure of finding technique, in spite of all efforts and all improvements, to cope with the task of maintaining the established discovery rate in the face of the ever smaller number and the greater obscurity of the pools remaining to be discovered. Even the recent remarkable progress in deeper drilling has not been sufficient to overcome the difficulty."

James McIntyre[9] has pointed out that since the discovery of the East Texas Field in the fall of 1930 to the end of June, 1935, 73,000 wells have been drilled. The only field of major importance discovered during this period was Conroe in 1931.

PRESENT PRODUCING AREAS.

Only three states, Arkansas, New Mexico and Montana, have been added to the list of productive states in more than twenty-five years, and neither the present production nor the proven reserve of these states is important from the national standpoint. The only important producing areas that have been added in the older producing states are the Panhandle (Texas) and the West Texas-Southeast New Mexico district. Fields which would double the combined present prouction of Indiana, Illinois, Kentucky, Ohio, West Virginia, and Montana would be negligible from the national standpoint and the combined increase would not equal the normal decline in one or two years of a single flush field in Texas or Oklahoma. With the exception of the Gulf Coast in Texas and some of the California fields, these areas as well as less important districts have been thoroughly explored to the deepest producing sand and often to the bottom of the sedimentary rock section. Along with deep drilling, production has been increased by extremely rapid exploitation of areas already producing and by geophysical methods of exploration. In other words, the complete exploration of an area is now much more rapid than was the case a few years ago.

Notwithstanding the aid of geophysical methods and extensive wildcatting, no market-breaking fields and very few of major importance have been dis-

[6] "Petroleum Times," 33, 346 (1935).
[7] Petroleum Investigations: Hearings Subcomm. H. R. 441—73d Congress.
[8] Pratt, Wallace, "Oil and Gas Journal," Sept. 5, 1935.
[9] McIntyre, James, "Oil and Gas Journal," July 25, 1935.

covered since East Texas in 1930 and Conroe in 1931. (A field of major importance may be considered to be one capable of producing a total of about 75,000,000 barrels of oil, which is about one month's supply for the United States.) With the exception of the Yates (Texas) pool, no really important shallow field has been found since the A. P. I. Committee of Eleven report was issued in 1925. The withdrawals from our proven reserves have been greater than the amount added by the discovery of new fields for at least five years.

Geological study has been very active. In the Gulf Coast Area in 1934, the list of geophysical activities included 60 seismographs, 40 torsion balance parties operating 117 instruments and eleven other parties using magnetometers, etc. The thoroughness with which this area had already been worked out for shallow fields is indicated by the fact that in the fields which were four years old or less at the end of 1933 the top of the producing horizon was less than 3000 feet in only one field, and deeper than 3000 feet in 15 fields. In the six 1934 discoveries the depth was 5000 feet in one, 6000 feet in one and below 7000 feet in four.

IMMINENT SHORTAGE OF PRODUCTION FROM PRESENT FIELDS.

During the years 1925 to 1933 the excess of domestic production over domestic consumption averaged about 75,000,000 barrels per year. This excess would have been wiped out, in the absence of important new discoveries, by two years' normal decline in only one or two of the flush fields, as shown by the following:

(1) The combined annual production of the Santa Fe Springs and Long Beach fields declined 82,000,000 barrels in two years, 1929- 1931.

(2) The Seminole (Oklahoma) district declined 95,000,000 barrels in four years, 1927-1931, in spite of the discovery of new pools in the area.

(3) Four of the principal fields in the West Texas area declined 87,000,000 barrels from their combined peak productions (1926-1930) to 1933.

(4) The five principal pools in the East-Central Texas district (Mexia, Powell, Richland, Currie and Wortham) declined from a combined peak production of 88,000,000 barrels (1922-1925) to 7,500,000 barrels in 1928, and less than 2,000,000 barrels in 1933.

PRORATION AND POTENTIALS.

The official "potential" figures, upon which proration is based, have given an entirely false impression of the actual production capability of many fields. "Potentials" are based upon the flow for short periods, from a few minutes to a day or two, of individual wells, or of "key" wells upon which the potentials of larger groups of wells are based. The absurdity of the exaggerated potential production of the East Texas field is shown by the fact that a late official determination gave this field an hourly potential of 10,000,000 barrels. At this rate, 240 million barrels per day, the total amount of producible oil estimated to be *remaining* in this field, would be produced in about one week.

The maximum rate of production which will give the greatest ultimate recovery at the lowest cost, called the *critical production*, is also usually far below the official "potential." For example, the Yates (Texas) field was given an official potential production (March, 1931) of 5,508,000 barrels per day. It was found, however, that the flow had to be kept below about 100,000 barrels per day to prevent many of the wells from going to water. The umpire of the field estimated that the field could produce 3½ million

barrels in one day by unrestricted flow, but that 98 per cent of the wells would be showing water and that in 30 days the field could produce not more than 10,000 barrels per day.

The Hobbs (New Mexico) field has a daily "potential" of more than 2,000,000 barrels with an "allowable" production of 33,000 barrels per day. On account of water difficulties this allowable production could not be greatly increased without doing great damage to the field.

Restricted fields similar to Hobbs, Yates and Van, in which drilling has been controlled, promise to give a dependable back log of production at somewhere near their "critical" rate for several years to come. Although many of the more recently developed fields could have produced for short periods at rates greatly in excess of the rates attained, they would probably have been quickly depleted or ruined by such unrestricted production. A general study of field histories shows that the slower drilling and slower development and the natural conditions of the older fields were as efficient in restricting their rate of production as artificial restrictions are in most of the recent, rapidly drilled fields.

THE PRESENT SITUATION IN THE PRINCIPAL PRODUCING AREAS.

Since the report of the A. P. I. Committee of Eleven was published in 1925, much of the territory listed as probably productive has been condemned by drilling. The old producing areas in Kansas have now been drilled to the bottom of the sedimentary rock column. The large number of dry holes drilled in this area, 2334 in Marion, Butler, Greenwood, and Cowly Counties, condemns this area so far as important new pools are concerned.

The eastern and southern half of Oklahoma is similarly condemned for important new fields. Creek County, with over 2000 dry holes, and Okmulgee and Osage Counties, with more than 3000 dry holes each, show the extent to which these areas have been tested. There literally is not room between dry holes for an important new field in these areas.

The area now being actively exploited in Kansas and Oklahoma is a strip extending generally northward from the Arbuckle Mountains. Practically all of the new fields in Oklahoma and most of those in Kansas are producing from the deepest possible productive horizons (Ordovician). This entire area has been thoroughly worked by surface and subsurface geological methods, closely core drilled, completely worked over with magnetometers, and the Oklahoma portion completely and the Kansas area largely explored with the seismograph. At the rate at which the structures thus found are being tested it is safe to say that any pool of even moderate importance now remaining in this area will be discovered within the next year or two.

In Texas the broad central belt with the San Antonio and Mexia-Powell districts on the eastern, and the Ranger-Breckenridge and Wichita Falls districts on its western margin, is now condemned by deep drilling for important new pools. The area of the Caddo or Sabine uplift, with a few small pools in Louisiana on its crest and the East Texas field on its western margin, can be said to be condemned for important new production, down to the Trinity beds, in which there is some though not a great chance for production important from a national standpoint.

It is impossible within the limits of this paper to discuss all the producing or potentially producing areas in detail. Three areas in Texas are being actively exploited, the Panhandle, West Texas and northeastern Gulf Coast districts. The Panhandle district is well worked out within the present outline of the area, but deep drilling on the flanks of the uplifts may discover something of importance. Small pools are still being found along the northern margin of the West Texas area. The district was discovered in 1923, and all

the more important fields were discovered by the end of 1927. Deeper drilling, into the Ordovician, has been very disappointing, yielding less than 20,000,000 barrels deep production in the Big Lake field up to the end of 1933. The Gulf Coast belt of Texas and Louisiana was thoroughly worked over for shallow production during its early history. Of the 81 separately listed fields only six have so far approached or exceeded 75 million barrels and the whole area has produced little more than a year's supply for the United States. Conroe, discovered in 1931, is the only recent field of major importance in this area. Since the discovery of Conroe, more than 300 wildcat wells drilled in this area have yielded only twelve new prospects or pools, none of which as yet promise to be as important as the better, older fields. The deep sands of the Gulf Coast tend to produce gas instead of oil.

The outlines of the probably productive areas in California are drawn today practically as they were twenty years ago. Ventura Avenue in 1925 and Kettleman Hills in 1929 are the only contributions from this state in recent years which now appear to be of great importance.

Deeper drilling has given practically no results in the old Appalachian area, where wells have been drilled to a depth 4000 feet below the deepest known production.

The production of Michigan to the end of 1933 was 27½ million barrels, or the equivalent of about 10 days' domestic consumption. The production in 1934 was less than one per cent of the United States total.

Of the Rocky Mountain states, Wyoming is by far the most important, having produced since 1889 2.2 per cent of the United States total production, or 4½ months' supply. In the entire area of the Rocky Mountain states, years of exploration and the drilling of more than 2500 dry holes, which have tested most of the known structures, have revealed only two important fields, Salt Creek and Hobbs.

In an earlier optimistic estimate of possibly productive territory, the states of New Jersey, Delaware, Maryland, Virginia, North Carolina, South Caroline, Georgia, Missouri, Wisconsin, Idaho and Nevada were included in whole or in part. These now deserve little or no consideration as possible contributors of any importance to our future petroleum supply.

The possibly more promising areas, from the standpoint of their geology, are the northern plains states, North Dakota, South Dakota, Nebraska and Iowa, and the eastern Gulf Coast states, Mississippi, Alabama and Florida. Of these, however, it can now be said that the possibly productive areas have been much more thoroughly explored and more carefully tested than was any one of the major producing states before petroleum was found in important quantities.

INCREASING PERCENTAGE OF DRY HOLES.

One indication of the approaching exhaustion of the possibility of discovering important new fields is the increasing percentage of dry holes drilled. Although our geological knowledge is much more accurate and extensive, and many more geologists are employed in finding oil than in earlier years, the proportion of dry holes drilled has increased. In Texas this percentage fluctuated moderately below 30 per cent to 1917, descended to 17 per cent in 1919 and then rose steadily to 45 per cent in 1930. In Oklahoma the dry hole percentage ranged between 7 and 20 from 1904 to 1917, between 20 and 30 from 1918 to 1924 and between 30 and 35 from 1924 to 1933. In California the percentage of dry holes varied from 3 to 12 per cent from 1905 to 1922; then from 21 to 26 per cent from 1923 to 1930; was 49 in 1931; 48 in 1932 and 40 in 1933.

EFFECT OF PRICE ON PETROLEUM PRODUCTION.

The statistical history of the industry shows that although high prices have stimulated drilling they have not resulted in the discovery of important new fields in old areas which had previously been prospected thoroughly. Thus, in spite of the high crude prices during the war years, the combined production of the Appalachian states was 15 million barrels less in 1920 than in 1915.

The supply of petroleum has been more effective in controlling the price than the price has been in controlling the supply; the effect of price on production has been very remote. High-price levels will increase somewhat the amount of petroleum recovered in the later stages of the productive life of the fields, but will not necessarily result in the discovery of new fields of sufficient magnitude to maintain our rate of production.

PROVEN AND UNPROVEN RESERVES.

Current estimates of proven reserves vary from about 10 billion to 13 billion barrels. This may seem to be a wide variation; but the difference is caused principally by different interpretation of what is proven territory. Some of the more liberal estimates evidently include some acreage of doubtful character. In addition to the proven reserve, an unknown amount of oil lies in undiscovered fields. The facts presented above indicate in a very qualitative way what the chances for discovering new producing areas, or important new fields in old producing areas, are. In view of the facts, there is no assurance that the proven and unproven reserves are large enough, or that new discoveries will provide production fast enough to maintain the present position of our petroleum industry. The available evidence indicates that we will be fortunate if we can supply our own consumption at its present rate for any period longer than five years, and a shortage may develop sooner should the consumption increase. It may be repeated that we have not supplied our total demand, including exports, for many years; but have used several hundred million barrels of imported oil.

INCREASED OIL RECOVERY.

The estimates of total oil recovery already given include that to be produced by such auxiliary methods of production as repressuring, and water flooding, where they have been shown to be practicable. Water drive is applicable to but very few fields. Even though this method is particularly favored by the conditions in the Bradford, Pa., field, and Bradford oil commands the highest price paid for oil in the United States, the effect of water flooding in increasing the petroleum production from Pennsylvania is shown in Figure 1. The American Petroleum Institute Report on Supply and Demand[10] comments that "Flooding is expensive and cannot be done on low-priced oil."

Water flooding was authorized in Pennsylvania in 1920 and the effect of this operation on this state's production was noticeable by 1925-1926. If we credit all the increase to water flooding this operation has raised Pennsylvania's production from 0.82 per cent in 1920 to 2.1 per cent of the total United States production in 1934.

Repressuring by gas, for secondary recovery, is also limited to sands of the general type of the Bradford, and no attempt has been made to apply it to

[10] American Petroleum Supply and Demand. New York, 1925, p. 105.

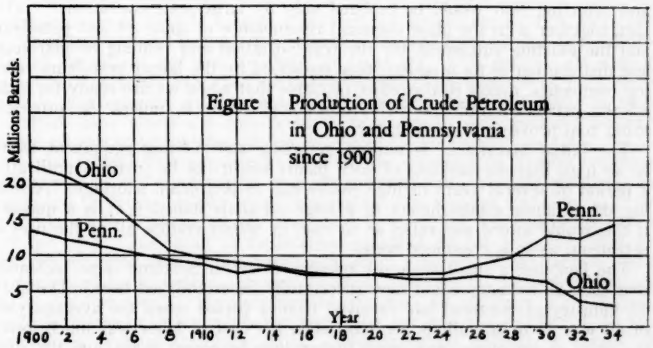

Figure 1 Production of Crude Petroleum in Ohio and Pennsylvania since 1900

deep, unconsolidated, variable, water-logged sands. It was first used in Ohio about 1912, but Ohio's production has declined steadily from 9 million barrels in that year to about 4 million in 1934.

Mining for draining or removal of old oil sand has not been attempted on a large scale in the United States. Driving tunnels in or below the sands, the method practiced at Pechelbronn, Alsace, is practically unthinkable in the unconsolidated sediments of the Gulf Coast and California. Gas given off by the oil would be a very serious if not insuperable obstacle to be handled. Actual mining of the sand has been suggested. Using data given by the A. P. I. Committee of Eleven, the average number of tons of sand required to recover a barrel of oil ranges upward from 3.2 tons in Montana. Kansas would require 13 tons; Oklahoma, 15 tons; California, 10 tons; Texas, 41 tons; Pennsylvania, 48 tons; Illinois, 38 tons, etc. These figures are not accurate, but they show plainly that only exceptionally rich sands under exceptionally favorable conditions can be mined for their oil content at any remotely possible prices.

SUBSTITUTES FOR PETROLEUM.

Shale has for long been regarded as guaranteeing a plentiful supply of oil in the future, or as supplementing our petroleum supply, and so it may,—*at a price*. The price ranges of petroleum in the United States have not been high enough to inspire any attempt to retort oil shale on a large commercial scale. This very fact makes it impossible to say at what price level, for crude petroleum, shale oil can begin to compete. Perhaps $2.50 per barrel for average Mid-Continent crude at the well may be such a price level. For the great oil shale deposits of Colorado, Utah and Wyoming the estimates of the costs of mining vary from a low figure of 40 cents a ton for open cut methods to as high as $2.50 a ton for selective mining. According to the Bureau of Mines, the estimated average yield for a thickness of 500 feet in the famous Green River formation of Colorado is about 15 gallons per ton, selected sections running much higher.

In the second report (1928) of the Federal Oil Conservation Board, it is stated that "an oil shale industry in the United States, to be successful would need to be operated on an extremely large scale, possibly on a larger scale than any mining operations" and that "the small shale operator would doubtless find it practically impossible to compete with the lower costs of mining

and retorting that would be realized only by large-scale operations." This fact, together with the close chemical resemblance of shale oil and petroleum and the existing equipment for the transportation and refining of petroleum and distribution of its products, now possessed by the larger petroleum refining companies, makes it altogether probable that when we are ready for shale oil the petroleum refiners will produce and refine it, unless the processes using coal prove to be the cheaper.

The initial investment in mining, retorting and refining equipment would be so high that the building of such plants might not be justified until after a period of several years of high prices due to petroleum shortage. Assuming the ultimate establishment of a huge oil shale industry, it is a question if this would afford any relief as to cost, or would restore all of the uses of petroleum as it is consumed today.

The fact that a small shale oil industry exists in Scotland is no indication that such an industry could now successfully be established here. The shale oil industry of Scotland has survived from a period when the average yield of oil was 33 to 36 gallons per ton, when the cost of labor was much lower, the price of petroleum was much higher than in recent years, and the shale mined much nearer the surface than now. It now costs five to six shillings per ton to mine the shale and with the best Scotch economy the crude shale oil costs 4.5 pence per gallon (British) or about $3.02 per barrel. Furthermore, the gasoline from this source is exempt from a tax of 8 pence per British gallon or 12.8 cents per U. S. gallon, which tax is paid by imported gasoline or gasoline made from imported petroleum. The shale oil manufacturers also enjoy a tax recently imposed, on Diesel oil from foreign sources.

It is well understood that the coking of coal cannot produce sufficient motor fuel to be a factor in the situation. The entire tonnage of bituminous coal retorted in the United States in 1926 yielded 1.02 per cent of our motor fuel requirement in 1925. Since then gasoline consumption has increased nearly 50 per cent and our benzol production has declined.

It has been suggested that our future motor fuel requirement could be produced by pressure cracking of the tar made by low temperature carbonization of coal. It is possible that up to a certain point such a process might be a factor in alleviating a shortage of motor fuel, but it should be pointed out that several attempts to carry out the low temperature distillation of coal in the United States have been industrial failures. Low temperature carbonization of coal and pressure cracking of the tar was discussed by A. C. Fieldner in a report by the U. S. Bureau of Mines to a subcommittee on petroleum of the last Congress,[11] and stated that, assuming a total yield of 10 gallons of motor fuel per ton of coal, 136 million tons of coal would have yielded only 8 per cent of our gasoline in 1932. Fieldner concluded that, "We must turn to a process in which motor fuel is the principal product rather than a by-product."

On the other hand, the trend of large scale developments in England and Germany is toward hydrogenation of coal. In the latter country, coal hydrogenation yields about 80 gallons per short ton of coal. It is reported that by 1936 the German plants will be hydrogenating 2.5 million tons of coal annually, producing about 200 million gallons of gasoline in this way. In England a coal hydrogenation plant has been erected which is reported to have an annual capacity of about 55 million U. S. gallons of gasoline when operating on coal and tar, or about 70 million gallons when hydrogenating tar.

[11] Petroleum Investigations, *loc. cit.*, p. 1375.

It should be particularly pointed out that in England gasoline made by hydrogenation of coal is exempt from the tax, equivalent to 12.8 cents per U. S. gallon, and in Germany the process is favored by a similar tax exemption of 220 marks per ton, or about 24 cents per U. S. gallon. It cannot be assumed in either case that the tax differential is a measure of the difference in cost between gasoline from petroleum and from coal, since in both countries these plants are considered to be a step in their national security programs and to be maintained and developed by the indirect subsidy.

In the United States the next step in the direction of greater gasoline yields may be the combination of hydrogenation with pressure cracking, as suggested by Russell, Gohr and Voorhees.[12] The average gasoline yield by cracking alone is about 60 per cent, and by complete hydrogenation about 108 per cent. The latter is an increase of about 80 per cent over that by pressure cracking alone. The hydrogenation of a portion of the recycle stock as suggested by Russell, Gohr and Voorhees provides an optional flexibility as to gasoline yields. As indicated by the fuel oil statistics given below, there is relatively little margin for increasing our gasoline production by the installation of more cracking units. Hydrogenation provides a means of substantially increasing the gasoline yield; less cracked fuel oil would, of course, be produced.

The yields of gasoline from two German brown coals as the process is now operated (1935) have been given by Pier as follows:[13]

OIL YIELDS ON HYDROGENATING TWO BROWN COALS.

	I	II
	per cent	per cent
Carbon in a.m.f. coal	68	68
Bitumen in a.m.f. coal	13	8
Yields		
Gasoline	33	37
Lubricating oil	13	13
Paraffin	11	7

In Germany and England, the scale of industrial operations indicates that motor fuel is more cheaply produced by the hydrogenation of coal than by the reduction of water gas.

It will be noted in both distillation of shale and the hydrogenation of coal, that several years must elapse to build them up to any magnitude. In the event of a national emergency such as war, the emergency would be settled one way or another long before any large part of our gasoline demand could be supplied from the auxiliary sources.

Another possible source of motor fuel, lubricants and wax is a modification of the synthetic methanol process. In this process, upon which work was started by the Badische Co., by F. Fischer and Patart in 1913-1914, water gas is reduced by excess hydrogen to light hydrocarbon oils. According to data recently published by Fischer,[14] 1000 cubic feet of water gas will yield about 1.1 gallons of light hydrocarbon condensate, part of which is suitable for motor fuel. The yields are lower than in the case of synthetic methanol and the costs per gallon higher.

The lubricating oils made by Fischer are made by polymerizing the unsaturated hydrocarbons in the lighter fractions, or by chlorinating and treat-

[12] "J. Inst. Petr. Techn. 21," 352 (1935).

[13] "J. S. C. I., 54," 284 (1935).

[14] Brennstoff Chemie, 16, 1 (1935).

ing with metallic aluminum. These oils have the characteristics of lubricating oils of the paraffinic or Pennsylvania type. However, it should be pointed out that the lubricating oil now manufactured in the United States represents less than 3 per cent of the crude and that much more could be manufactured from our present crude supply, if it were needed. Lubricating oil has also been manufactured by the polymerization of cracked paraffin wax and other olefins, and by the hydrogenation of heavy oil residues. We could therefore manufacture an adequate supply of lubricants from a much diminished crude supply.

PROBABLE EFFECTS OF A PETROLEUM SHORTAGE.

Shortage or surplus depends upon the rate at which petroleum can be produced, and not on the total amount in reserve, nor on the substitutes which may be available in the course of time, at some higher price level. Substitutes, such as shale oil, hydrogenated coal, increased efficiency in utilization and imports, will affect the stringency of a shortage, but will not prevent one.

Under the conditions of an oil shortage, refineries with little or no production of their own will operate, if at all, under an increasingly serious handicap. According to the survey of domestic reserves held by American companies, made recently by J. H. Lewis of Goodbody & Co., 91 per cent of our proven reserves are owned or controlled by nineteen companies. That the executives of certain companies realize the approaching situation is possibly indicated by the fact that at the end of 1935, fifteen companies held in fee or under lease 30 million acres of non-productive land. A few companies have greatly increased their reserves in South American fields in recent years.

Relatively abundant foreign supplies of petroleum with a shortage of our own supply will tend to raise our prices for petroleum products in relation to prices in other countries and finally bring our prices up to or above theirs. High price levels will certainly cause a shift in the proportions of the principal refinery products, the products of lower value becoming more and more restricted with advancing prices. The trend in recent years with respect to the major products is as follows:

TABLE II

PRINCIPAL PRODUCTS FROM CRUDE OIL

Year	Gasoline and Naphtha per cent	Kerosene per cent	Gas Oil and Fuel Oil per cent	Lubricants per cent
1914....	18.2	24.1	46.5	6.6
1918....	25.3	13.3	53.5	6.2
1920....	26.1	12.7	48.6	5.7
1922....	28.8	11.0	50.9	4.7
1924....	31.2	9.3	49.8	4.3
1926....	34.9	7.9	46.9	4.1
1928....	37.4	6.6	46.7	3.8
1930....	42.0	5.3	40.2	3.7
1932....	44.7	5.3	35.9	2.7
1934....	47.4	6.0	37.5	2.8

The industries that will be affected by higher prices and the conservation of fuel oil for cracking are indicated in the following data from the U. S. Bureau of Mines.

TABLE III

USES OF GAS OIL AND FUEL OIL IN THE U. S.

(in 1000 bbls. of 42 gallons each)

Industry	1926	1928	1931
Railroads	72,217	70,680	58,150
Steamships	79,287	89,942	83,558
Gas and electric power plants	33,651	30,901	24,490
Iron and steel products	16,102	19,429	12,855
Smelters and mines	8,941	6,897	3,626
Chemicals and allied industries	——	3,400	2,907
Automotive industries	1,603	3,628	1,783
Textiles	——	4,586	5,683
Paper	——	2,792	1,833
Logging and lumber	3,183	2,673	1,667
Cement and lime	5,586	5,223	2,434
Ceramics	3,216	2,995	1,598
Foods	7,674	6,488	5,660
Other manufacturing	23,017	10,023	9,998
Commercial heating	13,874	16,427	15,731
Domestic heating	3,905	5,971	10,466
Furnace oils, domestic	6,300	8,300	14,213
Oil companies	48,701	50,044	51,196
Miscellaneous	7,514	12,757	10,266
U. S. Navy	6,541	8,368	9,203

It should be pointed out that the above figures include the fuel oil produced in cracking for gasoline. In 1934 the total domestic consumption of fuel oil was 325 million barrels, of which 178 million barrels was residual oil from cracking. The remaining uncracked fuel oil is mostly heavy oil of relatively little value as cracking stock. This shows very clearly that our supply of motor fuel can be increased very little from our present crude supply by cracking without cutting into other important established uses. As noted above, the manufacture of gasoline from heavier oil by hydrogenation eliminates the formation of residual fuel oil entirely, and the combination of cracking and hydrogenation recommended by Russell, Gohr and Voorhees decreases it substantially. In so far as these methods are applied, gasoline production may be increased at the expense of fuel oil. Without relief by importing more crude, a decrease of 12 per cent in the supply of average grade of crude would require the diversion to cracking stock of an amount of gas oil and fuel oil equal to the combined amount now used as furnace oil, by commercial and domestic heating, by the gas and electric industry plus all of the kerosene now produced. Or such a decrease in crude production, if compensated for by increased cracking, would require the diversion for cracking to gasoline, of more fuel oil than is now used by the U. S. Navy and all the steamships supplied by American fuel oil.

What would naturally happen, unless relieved by greater imports, would be a readjustment of prices all along the line. The trend shown in Table II may be expected to continue.

If the cost of gasoline becomes high enough to consider any of the substitutes already mentioned, the use of small, low-powered automobiles may be favored, which would reduce the gasoline requirement and would have far-reaching effects on the automobile and allied industries. The effect of relatively high motor fuel costs, plus high taxes, in favoring low-powered cars has already occurred in Europe to a conspicuous degree, gasoline now retailing at 86 cents per gallon in Italy and 56 cents per gallon in Germany.

The use of Diesel oil in motor cars is evidently possible. If such fuel in suitable engines meets the popular favor, Diesel oil will supplement but can never replace gasoline as a motor fuel. Diesel oil now carries a motor fuel tax in England. Such a development would greatly diminish the need for cracking processes to convert gas oil, or Diesel oil, to gasoline. In so far as greater car mileage may be realized from Diesel oil and taking into account the formation of coke, fuel oil residues and gas formed in converting heavier oils to gasoline by cracking, the utilization of oil in Diesel engines would aid materially in alleviating the effects of a domestic oil shortage.

CONCLUSION.

Petroleum geologists have called attention to the increasing difficulty and decreasing rate of oil discovery. Geological exploration and drilling have greatly extended our knowledge of potential oil producing areas and the conclusion is drawn that a shortage of domestic production may be expected in five to eight years. Whether increased imports from foreign fields will prevent a substantial rise in the petroleum price structure, and for how long, are open questions.

At higher price levels for crude petroleum and its products, petroleum substitutes will begin to compete with natural petroleum. Some of these have already been carried out on a sufficiently large scale, in Europe, to assure us that they will alleviate the stringency of a petroleum shortage. The trends and probable readjustments in the industry are considered.

That a difference of opinion exists in the industry as to the relative imminence of a domestic petroleum shortage is reflected in the number of companies that have made a great effort to increase their reserves in recent years, and to carry out research looking to the future, and those who have not.

Any attempt at conservation that would bring higher prices might be popularly interpreted as favoring the industry at the expense of the consumer. Questions concerning proration, unit control of fields and reasons for the lower cost of production in foreign fields are beyond the scope and purpose of the present paper. The prospect appears to be a continuation of the conditions of production and refining that we have had in the last few years until the indicated shortage materializes.—Presented by "The Chemical Foundation," 1935.

NAVAL INTEREST IN HIGH SPEED.

EXTRACTS TRANSLATED FROM ARTICLE BY COMMANDER LEMONNIER, FRENCH NAVY.

In our age the tendency is always for greater speed and naval vessels have not escaped this rule. The last twenty-five years have witnessed sensational progress in this respect both as regards naval and merchant vessels. Nothing shows this more clearly than the *Normandie*. This huge ship is capable of

maintaining a speed of 30 knots and her consumption at 29 knots is less than that of the *Ile de France* at 24 knots, notwithstanding the fact that her displacement is 25,000 tons greater.

Since speed is not less important for the Navy than for the Merchant Marine, corresponding progress has been made. To illustrate this, the *Jaguar* in 1926 made 36 knots, the *Verdun* and *Bison* 40 knots; in 1931 the *Albatros* 42 knots, and the *Gerfaut* 42.7 knots, followed by the *Cassard* in 1933 with 43.4 knots. Finally *Le Terrible* attained the impressive speed of 45 knots.

In this great advance in speed by the French, the British Navy has been somewhat skeptical and the following arguments are advanced against great speeds:

1—that a vessel cannot continue to make her trial speed in service,

2—that formations cannot maneuver at this speed, and

3—that the qualities of endurance and protection have to be disproportionately sacrificed.

The writer answers these objections with the very logical argument that if we assume a service speed of nine-tenths the trial speed the trial speed still remains an indication of what is to be expected in service.

Second, that great speed gives great flexibility of maneuver, for at a formation speed of 25 knots, a 40-knot ship is infinitely easier to handle than a 30-knot one. The argument on the third point is less convincing but takes the line that fleet action is comparatively rare in naval warfare, and that to fight one must first find the enemy. If speed is not provided, opportunity for favorable action will not arise, or such a fleet may be forced into action under unfavorable circumstances.

The writer then points out that with the existing greatly improved machinery, higher speeds can be obtained on the same tonnage, and he discusses the speeds of the different classes of vessels, from battleships to submarines. He reaches the following conclusion as the proper speeds for new construction:

Battleships: 28 to 34 knots.

Aircraft Carriers: Not less than 32 knots.

Cruisers: Speed will vary between 34 and 38 knots but will probably stabilize in the vicinity of 35-36 knots.

Light Vessels: Not less than 40 knots.

Submarines: 15 to 18 knots.

In conclusion, the author disputes the statement that the naval interest in high speeds is more theoretical than real. All nations are in accord that they must give the greatest possible speed compatible with other necessary characteristics. Speed must never be obtained at the expense of cruising radius or a robust hull. The final possibilities have not been reached and progress continues. A speed of 50 knots for light vessels will be attained in a few years. In closing, the writer points with pride to the fact that the present speed records, both merchant marine and naval, are French. At a moment when the ship construction industry is suffering from the depression, it is pleasant to note its possibilities.—"Journal de la Marine Marchande," 17 October, 1935.

OUR NEXT BATTLESHIPS.

The Need for Speed.

By "Observer."

The approaching end of the self-imposed prohibition on battleship construction by the three principal naval Powers and the activities of France, Germany, and Italy in building new ships of that class are naturally causing increasing interest in the question of the design of our own future capital ships. This was the subject set for what proved to be one of the most popular and interesting R.U.S.I. Gold Medal Competitions of recent years. The general trend of opinion among those who took part in the competition, as shown by the published summary of proposed battleship types,* inclined towards a ship of about 25,000 tons, having a speed of 24 knots, with a main armament of eight 13.5-inch guns, and an auxiliary one of a dozen 4.7-inch combined A.A. and anti-torpedo-craft guns; well armored and possessing great endurance. Possibly the fact that there has been much criticism of the immense size and cost of modern battleships and the knowledge that the British Admiralty have expressed readiness to accept an international limitation of 22,000 tons, combined to exert a moderating influence on the demands of the essayists; but, whatever their other merits, nearly all the proposed designs suffer from the grave defect that they are too slow.

There are still those who, like the so-called Custance school of pre-War days, argue that speed is not of primary importance in battleships; but the lessons of innumerable tactical exercises, to say nothing of those which should have been learned from the late war, and from the battle of Jutland particularly, are opposed to this doctrine.

In considering this question of speed, we should keep in mind that our main object in possessing a battle fleet is that it shall be capable of meeting *and destroying* the battle fleet of any potential enemy.† True, it might effectively cover the operations of all lesser units without fighting a fleet action, even as the Grand Fleet did up to the date of the battle of Jutland. It might do so even more effectively if, as the result of an encounter which was not a fight to a finish, the enemy battle fleet was so discomforted that it returned to harbor and refused to risk another general engagement, as was the case after that battle. Yet, until the enemy's battle fleet has been completely destroyed, it must continue to be a menace to our sea security and a factor in disputing that dominance of our sea power which will make for the speedy termination of hostilities. In short, our battle fleet must not be regarded merely as a force which, by clever strategy, can be interposed between the enemy battle fleet and our sea communications, but one to be used to meet and sink its principal opponent.

STRATEGICAL AND TACTICAL NEEDS.

Now, success in a fleet action is dependent on three things—the strategical plan which brings about the meeting with the rival fleet at the right time and in the right place; the tactical handling of the ships once action is joined; and, last but not least, the fire effect of their guns. For the first, superior speed is a supreme advantage, especially with the advent of air reconnaissance; for the two others it is indispensable.

* See Journal for May, 1935, p. 276-7.

† The surrender of an enemy fleet has, of course, the same effect as its destruction; but whereas the former may be one of the fruits of victory, the latter will be a potent factor in hastening peace.

Last year's Gold Medalist seems to have overlooked the fact that the success of a strategical plan can only be gauged by the outcome of the subsequent battle when he says* "the means of compelling an action are strategical rather than mechanical," and his example of "intelligent anticipation" which enabled the *Inflexible* and *Invincible* to cross the Atlantic at 12.5 knots and yet reach the Falkland Islands twelve hours before von Spee, fails to take into account the fact that it was the superior speed of our cruisers which enabled them to lay the German squadron by the heels and which led to their destruction. But for that superior speed the "strategic plan" would have had no tactical or practical result, because the enemy would have merely disappeared again into the blue. Nor is it sufficient to say that the speed of our new battle fleet "should primarily be such as to insure that it has a reasonable chance of supporting its cruisers"; its speed might be adequate to meet the strategical requirements of a particular disposition of our cruisers in relation to our own battle fleet and that of the enemy, but it might still be insufficient to insure that the enemy battle fleet shall be forced to fight when it is met.

When we come to consider the tactical requirements of a battle fleet we must be severe realists, not to say materialists; we must think continually in terms of "fire effect" and not be led to theorize by confining ourselves to a study of the relative positions of black and white "slugs" or diagrams of relative courses—own and enemy's. It is damage to the enemy ships which is the ultimate object of all the gyrations of a fleet in action, and of all the ingenuity spent in designing the units which compose that fleet. The be-all and end-all of tactics is to hit an enemy with greater effect than he can hit us, and the accomplishment of this depends on a number of factors; but the primary essentials can be summed up as:—

(*a*) Bringing the greatest possible number of the guns of our ships to bear simultaneously.

(*b*) Distributing our fire so that it will have its maximum effect.

The first is, obviously, dependent on getting and keeping all our ships in action; if at the same time we can so engage the enemy that the guns of a part of his fleet will not bear or range on some of our ships, so much the better.

Distribution of fire is mainly a matter of fire control—both fleet and individual ship, and is outside the scope of the present article.

If we are to be able to "get and keep all our ships in action" *no matter what the enemy may want to do*, clearly we must have superior speed. It has been argued that a battle fleet with inferior speed may neutralize the threat of a concentration on the van by turning on interior lines; but, if ours is the slower fleet, this presupposes that the enemy is anxious to engage and will obligingly remain within range on an outer circle, while our fleet retains its relative bearing on an inner arc—an extremely improbable situation. If the two fleets are equally matched and both anxious to engage, the faster one will certainly endeavor to derive some tactical advantage from its superior speed—such as working into a better position as regards light for fire control or air attack, or concentrating on the rear—a more difficult situation from which to extricate a slower fleet.

What is more important, however, from our point of view, is the question of engaging an enemy who is reluctant to let us get and keep all (or any) of our ships in action; because, except in the unlikely contingency of our fighting a fleet action with the United States, our battle fleet will, we hope, always be stronger than that of our enemy. Before deciding on the characteristics, and particularly the speed, of our new battleships, it behooves us, therefore,

* JOURNAL for May, 1935, p. 265.

to study those of the battleships of other naval powers, especially the ships which have been built or laid down since we tied our own hands by signing the London Treaty.

FOREIGN BATTLESHIPS.

To begin with, there is Germany, who has completed two "pocket" battleships, the *Deutschland* and *Admiral Scheer*, credited with a speed of 26 knots and armed with 11-inch guns; a third ship of the same class is building. Obviously, these ships are never going to risk action with our battle fleet except, perhaps, to harass the van or rear at long range when light and other conditions may temporarily enable them to do so without undue risk. With the exception of our three battle cruisers, the *Hood*, *Repulse*, and *Renown*, we have no ships both fast enough and powerful enough to bring these new German ships to action. Germany is now building two more battleships—vessels of 26,000 tons, which are also, it is stated, to mount 11-inch guns. It is inconceivable that these ships will not be greatly superior in speed to our existing battleships. Again, therefore, the situation is that until we have ships which are at least equal to these in speed and armament, only our battle cruisers could bring Germany's new battle fleet to action—and she will have five ships to our three until we have completed our new battleships.

France has a number of old battleships which are inferior both in speed and efficiency to our existing ships; but she has two 26,500-ton ships, the *Dunkerque* and *Strassburg*, completing. These vessels have an estimated speed of about 29 knots—practically that of our ageing battle cruisers, and their armament is eight 13-inch guns as compared with the eight 15-inch of the *Hood* and the six 15-inch of the *Renown* and *Repulse*. Moreover, France is now building a 35,000-ton battleship, and a second one is to be laid down in 1937. These vessels are admittedly designed as a reply to Italy's new battleships; they are not likely to be inferior to the latter in speed, or for that matter in other respects.

Italy has laid down two 35,000-ton battleships which, according to Admiral Cavagnari, Under Secretary of the Navy, will have "a large radius of action with the greatest speed obtainable—notably superior to the battleships of other nations. * * * Today—and for no short period—they represent the most powerful ships in the world." Italy is also reputed to have taken in hand her older battleships, re-engined them and increased their speed up to some 26 knots. Here again, until we have new and much faster battleships, we might find ourselves in the uncomfortable position that we could not force the new Italian battle fleet to fight. The difficulty of interposing a slower fleet between a faster one bent on damaging a trade route such as that which passes through the Mediterranean is a further problem which may well give cause for anxiety.

It is clear that the whole trend of battleship design abroad is towards much faster ships, and it is most unlikely that the United States and Japan, when they start building again, will be content with existing speeds or anything approaching them. In fact, if our new battle fleet is to fulfill the primary object of forcing action on an enemy and fighting him to the finish, the ships must have a speed which we can put in round figures as being at least 30 knots.

SPEED, PROTECTION, AND ARMAMENT.

But, the critics will object, this will mean either exceeding the Washington tonnage or foregoing other essentials in the way of armament or protection. Displacement is, of course, the governing factor, and, if only for economic reasons, no one wants to see a return to a race in tonnage.

Whatever kind of agreement may emerge from the wreckage of the Washington and London Treaties, it is to be hoped that 35,000 tons, at worst, will remain the limit of battleships displacement; but up to that limit we must build.

The question then becomes one of what is to be surrendered if we are to have the speed we require on a given displacement. Today protection is second in importance only to speed, for, next to the necessity that our battleships must be able to get and stay where they are wanted, is the fundamental requirement that they shall be able to take reasonable punishment whether by shell, bomb, or torpedo, and remain afloat. Until these two essentials are provided for it cannot be guaranteed that their armament, however heavy and efficient it may be, will function with any certainty. In other words, if there must be economy in the weight of one of the three main ingredients—speed, protection, and armament—which go to make up the capital ship, it will have to be in the latter.

This may seem heresy to those who believe that the gun is the main consideration and the "platform" only an incidental; but again, the battle of Jutland showed us that the Germans were right in surrendering something in weight of broadside to better protection, and that they lost little or nothing in fire effect by so doing.

Within certain limitations, fire effect is dependent primarily on the weight of metal which actually hits the enemy in a given time, not necessarily on the weight of each salvo fired, or that of the individual shell. For instance, the fire effect of eight 14-inch guns mounted in twin turrets should not, in practice, be greatly inferior to that of nine 16-inch mounted in triple turrets: the rate of fire of each individual gun, and therefore of the salvos, should be greater in the case of the 14-inch armament. There is also the advantage of not having so many "eggs in one basket."

There are other ways in which weight might be cut down without detriment to protection or armament in our new battleships. The present writer is in cordial agreement with the majority of the essayists for the 1934 Gold Medal in believing that the torpedo armament should go. The torpedo is the weapon of the smaller ship and of naval aircraft; it has never justified the additional weight and space it has needed in a capital ship.

Further appreciable saving in weight should be possible if, as a number of the essayists suggested, the A. A. and anti-torpedo-craft armaments were combined; the number of different calibers of guns and control systems, platforms, etc., in existing capital ships has become almost grotesque. Top hamper and the undue elaboration of gunnery, wireless, and even navigational fittings should be rigidly restricted.

Great endurance would not seem to be called for in our battleships. It is not their mission to remain at sea for long periods, and only the American Navy seems to contemplate fighting a fleet action on the far side of the Atlantic or Pacific oceans.

In short, it is maintained that our new battleships must be fast—at least 30 knots, or they will not be able to fulfill the role for which they are to be built. They must be well protected or they may be sunk before their armament has proved effective. These two essentials having been provided for, all non-essentials should be ruthlessly eliminated to enable the most powerful armament to be carried on the limited tonnage.

A FAST SQUADRON.

One further consideration: there will inevitably be a period during which our battle fleet will consist of some old and slow ships, and some new and fast ones. The latter will be useless if they are not given ample freedom

of action in battle. At Jutland there were fast ships at each end of the line—the battle cruisers in the van, the Fifth Battle Squadron in the rear. When the main action was joined, the former had already experienced the grave disadvantage of speed without adequate protection and, rightly, did not again seek close action with the enemy's heavy ships; but at the other end of the line were three battleships which, although they had already been hotly engaged, were still in good fighting trim and had some six knots in hand on the speed of the fleet; yet for one cause or another they remained tethered to the slow main body, and their superior speed was completely wasted when it might have played a vital part in the engagement.

There can seldom be justification for dividing a battle fleet whose ships are homogeneous in speed, and generally there would be great risk in doing so. On the other hand, there is every reason to give considerable latitude to the Admiral commanding a squadron which is fast enough to harass the enemy without risk of being isolated and destroyed in detail. But best of all is a homogeneous battle fleet whose ships are at least the equals of those of the enemy in powers of attack and defence, and superior to them in speed. —"Journal of Royal United Service Institution," November, 1935.

MERCHANT SHIPPING AND THE NATIONAL DEFENSE.

ONLY 161 MERCHANT VESSELS ARE REGARDED AS SUITABLE FOR USE AS NAVAL AUXILIARIES ACCORDING TO A RECENT SURVEY. WE MUST PLACE VOTING-POWER BEHIND AMERICAN SHIPPING TO OVERCOME OPPOSITION FROM PROFFESSIONAL PACIFISTS.

Few of our citizens realize how dependent the Navy is upon an auxiliary fleet of merchant vessels. Now that a constructive effort is being made by the present administration to build our fighting ships up to treaty strength, naval officers who are close to the needs of the Navy are greatly perturbed over the lack of a corresponding increase in merchant vessels that must be depended upon to supplement the effectiveness of our naval establishment.

In this respect, latest reports on the status of our effective naval auxiliaries in the way of merchant vessels are far from encouraging and, if we are to have a properly-balanced fighting fleet, it will be necessary to take immediate steps to remedy this situation. If we continue to build up our fighting-ship strength while at the same time neglecting our commercial fleet, our navy will be unbalanced and not as effective as it would be if this serious gap in our fighting equipment were bridged. The condition of our auxiliary merchant fleet as to its effectiveness to aid the navy in a war emergency, is substantially as follows:

Based upon a recent survey conducted by the Merchant Fleet Corporation in conjunction with the Navy Department, it was found that we have a reserve fleet of only 161 vessels suitable for auxiliary naval service. This effective mercantile fleet suitable for auxiliary service has been divided into two categories, first, vessels in the class of the *America* and *George Washington,* both of which vessels were taken over from the Germans during the World War and re-named. Including American-flag ships, there are only 29 ships in this classification. In the second category are included what are called "second reserve ships." This class includes such vessels as the ex-German re-named *Mount Vernon* and *Monticello,* both of which craft are more than twenty-five years old. The second-reserve includes 132 vessels of this class. A third category includes a large volume of miscellaneous war-time built tonnage and old ships that are hardly worth preserving and cannot be classed as of any use as auxiliaries.

At least five times this number of ships should be available for use by the Navy as auxiliaries and we are therefore 744 ships shy of what we should have to meet any emergency.

Many of our citizens, observing what is now being done belatedly to strengthen our naval defense, are likely to forget that it is necessary for them to take a personal interest in the upbuilding and maintenance of the Navy. Voting power is what counts in Congress where the individual members who must vote on appropriations are constantly being bombarded by powerful pacifist groups who are opposed to any kind of preparedness. Without widespread national encouragement and support for the Navy from the average citizens, this great bulwark of our sea defense is at the mercy of shifting political currents. An incoming administration that might heed the protestations of the pacifists as was the case when the Hoover Administration was in power, could easily wreck the entire naval program.

Our national history is filled with illuminating instances where neglect of our sea power has caused us not only humiliating diplomatic defeats but disastrous outlay of both lives and national wealth when it became necessary to recover lost prestige through sea power. Thomas Jefferson practically scrapped the American Navy and his predecessors had to build it up in a hurry under unfavorable conditions at huge expense. When the World War broke upon us, we found it necessary to expend billions of dollars in haste to repair our neglect during peaceful years when the upbuilding of our sea power might have been achieved at a comparatively small fraction of what the emergency job actually cost.

Fortunately, world events are moving so rapidly in the direction of a crisis that opposition to national defense, while as active as ever and even more lavishly financed, is not likely to seriously retard the movement toward security. It cannot succeed if the citizens of our country cultivate an awareness toward the trend of events and demand protection for their lives and property.

However, a strange fact is noticeable today in our national psychology that should receive the serious attention of those who would uphold our institutions and perpetuate our form of government along the lines laid down by the Founding Fathers. In an editorial recently published, the San Francisco "Daily Chronicle" crystallizes this trend as follows under a heading, "No Money for Patriotism":

"Communism, Epic movements and even Technocracy have money. Their advocates are organized, their teachers are active. Booklets and newspapers promote their cause.

"While this is true, patriotic defenders of this Republic complain that there is no money with which to publish even a cheap booklet that could be slipped into an ordinary envelope—a booklet analyzing and defending the Constitution.

"The writer of this editorial chances to know of a simply, brief analysis of the Constitution—a clearly written exposition of this Republic, a convincing statement of the essentials of Americanism.

"This little work was published in 1919. It was highly commended by President Nicholas Murray Butler of Columbia, Elihu Root, dean of the American bar; Governor Frank O. Lowden of Illinois, 'Uncle' Joe Cannon, Secretary Leslie M. Shaw, serving under Theodore Roosevelt; H. L. Mencken, Richard Washburn Child and about fifty others, including editors of eminent newspapers.

"Published long before the present attacks on our form of government, it is wholly non-controversial—as little so as the multiplication table.

"A plan to republish it so it could sell for around $3 a hundred and be widely circulated was submitted to a number of wealthy men, some of whom

had been talking over radio, others who had organized movements to support the Constitution. The effort to elicit interest was a complete failure.

"One eminent attorney wrote that he had given so much time to the subject that he could do nothing, so he approved of the idea of submitting the proposition to a large organization supposed to be 'in funds.' This was done—a complete failure.

"An eminent and reputedly wealthy worker in the cause courteously approved of the idea, the cost of which for an initial experiment would be less than $500.

"This man wrote that his organization was hard pressed for funds, adding that 'patriotic movements are hard to finance but we hope we can help to carry out this distribution later in the campaign.'

"Thus one gleam of light broke the gloom. Meantime the propounders of a scheme to upset property, to follow Proudhon and Marx and Stalin and Sinclair are flooding the country with their printed arguments.

"There is no money for patriotism, no movement to issue an approved booklet, sound and clear, written for the masses and within the comprehension of ordinary men and women. True, it is a pity and pity 'tis 'tis true. What's the answer?"

To counteract this dangerous tendency, it should be the duty of all who can analyze the present trend, to do what they can financially and otherwise to dramatize the patriotic side of the shield. It is unfortunate that those among us who have something to say in opposition to these dangerous and disruptive forces, remain apathetic and, by their silence, give encouragement and support to ideas that may eventually destroy all that they revere and believe in.

There is no money in patriotism and there shouldn't be. But all of the varied groups opposed to preparedness—advocating weird social experiments—calling for the destruction of liberty and the Constitution—demanding the application to our country of alien schemes and discredited social and economic nostrums—sneer at anyone who raises his voice for patriotism and try to create the false impression that he is mysteriously benefiting by standing up for his flag and his form of government—"Marine Journal," 15 November, 1935.

THE NEW GERMAN SUBMARINE DESIGNS.

First Details of Three Types—Weight Saving Devices—The Latest Idea in Torpedoes.

(From a Naval Correspondent).

The first of the new German submarines, *U.1*, ran her trials at Kiel in the middle of August.

It may be deduced from this that construction of the vessel began long before Herr Hitler's speech of May 21 last, in which he threw off, formally, the naval shackles of the Versailles Treaty. There is good reason, indeed, to believe that the design for these vessels was approved in 1932, and that orders for engines, torpedo tubes and other parts were placed in the course of 1933. Technical details of the design have not been published officially, but from various sources it is possible to indicate certain trends of German submarine practice which are of interest.

It has been stated that the first of the new German submarines would be of 250 tons displacement. This is probably an understatement, as the designs to which her yards are now known to be working are for vessels of 300

tons, 500 tons and 750 tons, displacement. The surface speed ranges from 12 knots to 15 knots. Exaggerated statements have been current, orally, in Germany, that a new form of underwater propulsion had been discovered which would give their submarines a submerged speed of 8 to 10 knots. These were probably based on a misconception by a layman of the meaning of "submarine speed." At the same time, it is known that considerable advances have been made in heavy-oil engine design and there is talk in well-informed circles of a new form of oil fuel (even the patented name has been mentioned outside the dockyards) which is destined to make the German submarine service independent of foreign sources of supply.

Experience with the construction of the *Deutschland* and *von Scheer,* the two pocket-battleships, has been turned to account in the new submarines in the saving of weight. It is understood that the hulls are electrically welded and that special kinds of light metals have been used in the construction. As an instance of the lengths to which this has gone it is stated that the compressed air chamber of the new torpedoes is built of one such alloy.

Developments in special steels are not, of course, peculiar to Germany. British practice for some years past has steadily evolved lighter plating and lighter protective armour and it is no surprise that German technicians have proceeded along similar lines. The amount of weight that has been saved in the internal fittings of the new submarines has, however, resulted in the production of a ship that can carry six 21-inch torpedo tubes, with reserve torpedoes, on a 300-ton displacement, while the 750-ton design is believed to carry ten tubes—three aft, three forward and four on the beam. A very much lighter torpedo tube is one of the interesting new fittings and weight saved in the hull of the torpedo itself has been utilized to provide heavier bursting charges and increased engine power. It is probable that the new German torpedoes weigh 3000 Kg. and have a 300 Kg. bursting charge. Stories are current that part of the warhead is fitted as an incendiary bomb.

The saving of weight in the hull has not been at the expense of stability. The specifications require the submarine to dive successfully to a depth of 50 fathoms (300 feet) which is very nearly the record depth known in submarine navigation. New types of rotary pumps fitted for discharge of the ballast tanks and other improvements for the "blowing" of the tanks are said to have increased the speed with which the submarine can rise to the surface by 50 per cent.

Submarines are at present being assembled in five different yards. The work is largely standardized and fittings are being made almost on mass production lines and not always in the shipyards.

One difficulty that was foreseen when Germany renewed submarine construction does not appear to have arisen in so serious a form as was anticipated. In the 17 years that have passed since last her yards dealt with underwater craft, a new generation of workers has grown up which has no experience in this type of construction and it had been suggested that there would be difficulties in finding skilled men, with consequent delays in completion. The fact that *U.1* has already run her trials would seem to negative this suggestion, unless some specially selected squads were employed in her case. This, however, is improbable, because had such a thing been done, it would have been largely for the purpose of advertising to the world the marvelous technical efficiency of the German yards. The completion of the first submarine would have been widely advertised. Actually, the fact that *U.1* is finished has not been made known and, in Germany, is still unknown outside a small circle.—"Shipbuilding and Shipping Record," 12 September, 1935.

THE FUTURE OF WARSHIP CONSTRUCTION.

A Plain Non-political Statement About What Re-armament Means—Some Considerations Affecting the Government Policy.

(By Our Naval Correspondent).

Considerable confusion of thought has already been occasioned by party-warfare cries on the subject of the future building plans for the Navy. The subject must inevitably figure largely in discussions in constituencies that are concerned with shipbuilding, with iron and steel and with marine engineering, and it may be helpful to set out plainly the national and international position and to provide some statistics upon which clear thinking on the subject may be founded.

Our readers have already been provided with an outline of the probable British program,* and it is worth noting that although this forecast was quoted during a debate in the House of Commons by an Opposition speaker, its substantial accuracy was not challenged from the Government benches.

Some of the confusion of thought among electors has been occasioned by the use of the term "re-armament." Speakers of all parties have talked in general terms of "strengthening the Navy," giving (possibly unintentionally) the impression that the proposal is to increase the strength of the Navy relatively to the other Powers.

The plain fact is that the so-called "re-armament" is simply a rebuilding of the Navy to practically the same standard of numerical strength as was provided under the Washington Limitation Treaty.

The Navy is not so much to be re-armed as replaced.

There has been a naval holiday since 1922. The ships which were allotted to each Power under the Washington Agreement have aged in the ensuing thirteen years. Every naval Power today is maintaining its first line of sea defense, its battle-fleets, with vessels that have passed the age-limit of twenty years or will pass it within a few months. The position can be set out statistically thus:—

Capital Ships.
Over-age between 1936 and 1942.
Britain 13; U. S. A. 15; France 9; Italy 4; Japan 9.

Italy has begun to replace her over-age tonnage by laying down two 35,000-ton battleships. France has laid down two vessels of 26,500 tons each and projected one of 35,000 tons. Both these countries, it should be said, are within their rights under the Washington Treaty in building these replacement vessels. The United States has announced a program of seven ships of 35,000 tons each, to be started as soon as the Washington Treaty ends. And Germany has reappeared in the naval fields with two 26,500-ton ships already on the stocks.

Those vessels may not affect the quantitative strength of the fleets, but they most certainly affect the qualitative strength. A vessel built in 1935 is manifestly an advance on one built in 1915–1916. Otherwise we must assume that human thought and invention have stood still for twenty years—which is absurd.

When, therefore, the Government spokesmen talk of "strengthening the Navy" it is qualitative and not quantitative strength of which they are thinking. It would be better if they made that point clear.

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* "The Anglo-German Talks and Naval Re-armament," June 20, 1935, page 685.

The new capital ships to replace our aged *Queen Elizabeths* and *Resolutions* will be numerically equal to the existing classes, but will be superior to them in battle-worthiness, will be, in short, counterparts of the ships added to the Navies of the other signatories of the Washington Treaty.

The position is worse in the case of cruisers. Here is the statistical abstract:—

Cruisers.
Over-age between 1936 and 1942.
Britain 36; U. S. A. 7; France 4; Italy 7; Japan 13.

Qualitatively the British position in cruisers is much worse than in capital ships. The other Powers were so reduced in numbers of cruisers in 1922 that they have been able to build large numbers of new vessels, of post-war design, to bring their navies up to Treaty strength. Indeed, France and Italy, by not ratifying the London Treaty, have been free to build any number of cruisers, though their construction, while considerable, has not, actually, been excessive. Our cruisers are very largely of war-time construction and the need for replacement is urgent. The quantitative position is more controversial and political influences affect it, so that it must only be touched upon delicately in this place. The Admiralty formerly held that 70 was the minimum number of cruisers required by the British Navy. That contention was modified at the time of the London Conference in 1930 and by a "gesture" we reduced our total to 50.

That action has been the subject of very bitter criticism from inside the Navy and if there is to be any "strengthening" of the Fleet numerically, it will be in this class. At the same time, the professional man will realize that the replacement of 36 over-age cruisers in six years is in itself a program that will keep the available shipyards very fully occupied, and it would seem to be improbable that any Government would be likely to exceed that replacement program to any marked extent.

Our destroyer position is the most serious of all, numerically. Here we are faced with the fact that more than a hundred new vessels are required in the next six years to keep our flotillas up to Washington Treaty strength. The international table for this class (including flotilla leaders) is:—

Destroyers.
Over-age between 1936 and 1942.
Britain 108; U. S. A. 218; France 36; Italy 52; Japan 63.

It will be seen that we ought to lay down 18 destroyers a year or two complete flotillas and two leaders, in order that the Fleet in 1942 should be provided with the same number of modern destroyers as it possesses of mixed modern and aged craft today. Moreover, by 1942 the earliest of our post-war flotillas will be approaching the age-limit in its turn and will only be suitable for reserve and emergency duties.

To complete this summary of the rebuilding up to Treaty strength of the British Navy we may rapidly glance at this table of the submarine position:—

Submarines.
Over-age between 1936 and 1942.
Britain 28; U. S. A. 22; France 30; Italy 18; Japan 24.

It will be seen that in this type of warship the Powers are more nearly on an equality in over-age vessels than in the others, and so far as Britain is concerned it might even conceivably be a matter of satisfaction if no replacements were built.

Foreign opposition to the abolition of the submarine, however, is still deeply rooted, but this is unlikely to lead to any extensive "strengthening" of the British forces in this type.

No mention has been made of auxiliary craft—mine-sweepers, mine-layers, convoy sloops and the like—since the construction of these is not limited by treaty. But it may be recalled, as a hint, that at the end of the war we were using 726 vessels for mine-sweeping alone, of which 110 had been specially and urgently built for the work during the war.—"Shipbuilding and Shipping Record," October 31, 1935.

MARINE DIESEL ENGINE PROGRESS IN WASHINGTON.

One of the most interesting phases of marine Diesel engine development during the past three years is the manner in which the various Government departments which are concerned with the construction and operation of marine craft have utilized the Diesel engine for established methods of application, and also developed new and interesting applications which are having a strong influence on Diesel engine design in general.

These various departments have in the past kept closely in touch with the progress of marine Diesel engineering, but have lacked the opportunity for carrying out the many ideas that have been developed by their technicians. It is always a difficult matter to obtain appropriations from Congress, especially when they are for work that is non-political in character, and it became doubly difficult in depression times.

The adoption of a policy by the present administration for pumping Government money into industry in order to bring about a general business revival, gave these Government departments the opportunity that they had been waiting for for many years; that is, to improve existing equipment, replace worn out vessels with new ones, and to carry out a certain amount of construction that is of a somewhat experimental character. As a result of this situation, Washington rapidly became the focal point of the marine Diesel engine business in the United States. From time to time we have recorded in the pages of "Motorship and Diesel Boating" the progress of work on the miscellaneous types of Diesel engine driven vessels that have been laid down, and reference to our past issues will reveal a very interesting and varied program of construction.

A very ambitious program of construction was inaugurated with the funds made available by the first appropriation made by Congress for the purpose of starting public works and as experience gained in the matter of applying the Diesel engine to best advantage made it apparent that there were still more ways in which funds could be used as they became available, additional plans were prepared. At the time the second Public Works bill was passed, by which some $5,000,000,000 were appropriated, it was expected that it would be possible to carry out these plans and still further add to the rapidly growing fleet of Diesel driven Government vessels.

Although the vessels vary widely in character, from combatant ships of the Navy, to vessels designed for more peaceful purposes, such as dredging waterways or breaking ice in harbors, the majority of them come under the classification of military equipment because of the fact that their construction and operation fall within the cognizance of military departments. That this proved to be an unfortunate situation is due to a last minute amendment that was tacked to the Public Works Bill, on the insistence of Senator Borah, whereby no funds could be allotted for the purchase of construction of military equipment. This has had the effect of killing a number of important and interesting Diesel engine projects.

The Government departments that have been and are concerned with this marine Diesel engineering work, are the Navy Department, Coast Guard, Army Engineers, Quartermasters Department of the Army, Public Health Service, Lighthouse Service and the Department of Agriculture. As a matter of interest to our readers we have recently completed a survey to determine the present status of the various marine Diesel projects in these various departments.

NAVAL DIESEL PROGRESS.

In point of volume of work and also from the standpoint of its influence on the future of the Diesel engine industry, the work being carried out by the Navy Department is perhaps the most important, yet by reason of public policy it is the one about which the least can be said. The Diesel engine industry, however, should benefit very greatly by the rational attitude that has been developed in the Navy toward the Diesel engine as a type. We have commented previously on the concentrated attention the Navy is giving to Diesel engine development and our readers have been given a further insight into it through the medium of our March and April, 1935, issues, in which Lieut. Com. J. O. Huse discussed the whole problem of Diesel propulsion for naval vessels. The situation in regard to the Navy and Diesel engines can be summed up by saying that consensus of technical opinion in the service is that the Diesel engine has very definite possibilities in the naval service and its use will continue to increase rapidly as time goes on.

The Navy is not being carried off its feet by enthusiasm for the Diesel engine, but is carefully working out practical methods for utilizing the many advantages it offers for various kinds of service in the naval establishment, and developing methods for eliminating its disadvantages.

A very important step toward stimulating the Diesel engine industry was taken when the Navy some years ago established the policy of encouraging commercial builders of Diesel engines to develop designs of engines suitable for use in submarines. As a result of this policy, the submarines that are now being built are all being equipped with engines that have been designed and produced by privately owned industrial plants. Another result of this policy was to stop Diesel engine construction in the New York Navy Yard, where a number of submarine engines following closely German design, were manufactured during the period following the World War. Since then, however, legislation has been enacted making it mandatory that a certain percentage of all naval construction be assigned to Government plants. This has been interpreted to include Diesel engines and a portion of the engines for the new submarines will be built at the New York Yard.

The latest development in this phase of naval Diesel work was the awarding of contracts on October 1st for the machinery for six new submarines now under construction. A contract was let to Hooven, Owens & Rentschler for supplying all the engines for three of these vessels.

This marks the initial entry of the H. O. R. Company into the submarine engine field. This company some years ago purchased a license from M. A. N., in Germany and since then has been engaged principally in the production of large, 2-cycle, double-acting engines. It is of interest that a portion of the machinery on this contract will be supplied to H. O. R. by the Fairbanks-Morse Company, also a newcomer in this field.

A contract was let to the Winton Engine Company on the same day for supplying all the engines, complete, for equipping two submarines. For the sixth vessel, the Winton Company was given the contract to supply some of the parts for the necessary engines in a semi-finished state to the Navy Yard, New York, where the machining will be finished and the engines assembled.

A very interesting phase of naval Diesel engine development is one involving very small boats but which in point of volume represents probably the largest conversion job ever undertaken. It involves complete abandonment by the Navy of the use of gasoline for the launches and small boats of all ships and the substitution of Diesel power.

Some time ago Navy officials made a concentrated study of the serious danger encountered in the operation of gasoline launches, impelled to this action by the numerous fires and explosions occurring on small naval boats in spite of the rigid precautions that are possible only in a highly disciplined organization. As a result of this study, it was definitely decided that gasoline was too dangerous an element to be considered for further use on naval vessels. The obvious remedy was the use of Diesel engines, but the Navy was faced with the problem of securing engine types suitable for this highly specialized service.

This problem was solved through the cooperation of the engine builders and the first definite result was the awarding some time ago of a contract to the Buda Company for 148 small Diesel engines for installation in launches for new naval vessels under construction. At the same time a further contract was entered into with the Buda Company whereby the Navy was given the rights to manufacture engines to their design, and preparations were at once made for equipping the navy yard at Norfolk, Va., for the manufacture of these engines. This preparatory work is now practically finished and the Norfolk yard will very shortly begin production.

The magnitude of this job is realized when it is understood that for the next two or three years the navy yards will be fully occupied in turning out engines for new boats and will then tackle the problem of converting the existing boats. Since there are approximately 1800 boats involved, it will be seen that is a job of considerable magnitude.

Another phase of the Navy program is one involving the equipping of new vessels with emergency generating plants. This calls for a very wide range of engine size and its effect is already being felt in the form of a large volume of orders widely spread among engine manufacturers.

A type of naval floating equipment that is most adaptable to the application of Diesel propulsion is that represented by the vessels of the auxiliary service, including the many different types of craft required to maintain the battle fleet. It is an interesting fact, however, that this, the most logical point for application of Diesel propulsion, will probably be the last one to receive attention because of the difficulty of securing the necessary funds. It was expected that a step in this direction would be taken when a plan was drawn up for the conversion of five existing steam driven tankers to Diesel drive, a plan which we discussed fully in our December, 1934, issue. For reasons which we need not go into here, the Navy failed to obtain funds for this project from the first P. W. A. appropriation, but it was fully expected that when the second large appropriation became available an allotment would be made for this purpose. Unfortunately this hope was destroyed by the Borah amendment previously referred to, and at the present time this plan is inactive.

It is of interest to note in this connection, however, that there is a strong disposition on the part of some influential members of Congress to give the Navy an outright appropriation of a large sum of money for experimental purposes. It is a distinct possibility for the future that this action may be carried out and that the tanker conversion problem can be put through with this fund. It might be added that this conversion is distinctly a development project because of its direct bearing on the future application of Diesel engine drive to battleships. Possibility of some action in the matter of

auxiliaries is seen in the recently announced intention of the Navy Department to ask Congress for an appropriation of $18,000,000 for building up the auxiliary fleet.—"Motorship," November, 1935.

THE CASE FOR THE MODERN STEAM INSTALLATION.

WHEREIN THE DISTINGUISHED MARINE ENGINEER WILLIAM W. SMITH ANALYZES THE APPLICATION OF MODERN PRINCIPLES TO THE STEAM PLANT ASHORE AND AFLOAT IN HIS DISCUSSION OF CHARLES P. WETHERBEE'S MUCH DISCUSSED PAPER.

In his paper entitled "High Steam Pressure and Superheat Aboard Ship" read before a technical session of the Society of Naval Architects and Marine Engineers November 15th, the distinguished author, Mr. Charles P. Wetherbee, advanced a decidedly unorthodox viewpoint with regard to the application of advanced steam practice to naval vessels. But there was a distinct impression, supported in the course of discussion by Mr. Wetherbee himself, that his views, as expressed in this paper, were principally intended to stimulate realistic discussion and to throw into bold relief the tremendous technical advance achieved by the marine steam plant.

The paper, however, was immediately pounced upon by our esteemed contemporary "Motorship," as a peg upon which to hang a leading article entitled: "A Good Case for the Naval Diesel," wherein Mr. Wetherbee's very temperate analysis of high steam pressures and superheat was gleefully turned to the advantage of the Internal Combustionists.

The reply to Mr. Wetherbee's paper from the steam contingent was prompt and devastating, for he had furnished a "speaking cue" of more than usual significance and utility. As a matter of fact, it was an excellent thing to have these points brought forward by Mr. Wetherbee, and if he had not undertaken the job it would have been necessary to bring them into open discussion through some other channel.

Outstanding, as usual, among the staunch defenders of the marine steam plant was William W. Smith, chief engineer of the Federal Shipbuilding and Dry Dock Company, whose excellent prepared discussion was supplemented and amplified by a series of tabulations, which accompany this article and which place upon record the essential statistical data relating to the steadily advancing position of the steam plant ashore and afloat. Mr. Smith's discussion of the Wetherbee paper, together with the tabulated statistical information, follow:

To obtain a proper perspective it is necessary to consider progress in steam machinery generally; both in power plants and in ships.

For steam temperatures between 700 and 800 degrees there are hundreds of domestic and foreign power plants. Their construction and operation have become standardized and commonplace. It is generally known that they operate satisfactorily and that they are more economical than those of lower temperature.

For temperatures above 800 degrees there are a considerable number of plants, some of which are listed in Tables 1 and 2. Notable among the domestic plants are: The Ford Motor Co., with 900 degrees, and the Detroit Edison Co., with 1030 degrees. Of the foreign plants, there are twelve between 800 and 900 degrees and four above 900 degrees. It is understood that these plants operate satisfactorily, and are more economical than those of lower temperature. This is substantiated by their increasing number.

For temperatures between 700 and 800 degrees there are a large number of marine installations, some of which are listed in Tables 3 and 4. Their

TABLE 1.—DOMESTIC POWER PLANTS OF 800 DEGREES AND ABOVE.

YEAR	PLANT	STM. TEMP. DEG. F.	STM. PRESS. LB. GA.	CAPACITY K.W.
24	Houston Light & Power (Deepwater)	850	1365	----
30	San Antonio Public Service	810	1518	20,000
30	Detroit Edison (Delray #2)	1030	400	10,000
30	State Line, Indiana (a)	832	1200	150,000
31	State Line, Indiana (a)	825	1200	125,000
31	Wisconsin Power & Light	825	650	30,000
31	Virginia Public Service (Bremo Bluff)	825	525	15,000
32	Public Service of N.J. (Burlington)	860	750	18,000
33	Potomac Electric (Buzzard Point)	825	650	35,000
34	Detroit Edison (Connors Creek) (b)	825	600	90,000
34	Diamond Alkali (b)	800	725	10,000
35	Milwaukee Railway (Pt. Washington) (a)	825	1320	80,000
35	Phila. Elect. Co. (Richmond)	850	400	165,000
35	Ford Motor Co. (River Rouge)	900	1400	125,000

a. Reheat cycle. b. At turbine.

TABLE 2. FOREIGN POWER PLANTS OF 800 DEG. AND ABOVE

YEAR	PLANT	STM. TEMP. DEG. F.	ST. PRESS. LB. GA.	CAPACITY K.W.
24	Langerbrugge, Belgium	842	800	2,000
28	Withowitz, Poland	932	1700	19,500
28	Mannheim, Germany	878	1420	10,000
28	Siemenstadt, Germany	824	2272	8,000
29	Ilse Renate, France	930	1425	12,000
29	Issy le Moulineaux	842	825	57,000
30	Bradford, England	800	1100	10,000
30	Langerbrugge, Belgium	824	2840	20,000
31	St. Dennis, France	930	1000	7,000
31	St. Dennis, France	887	980	100,000
31	Trabovise, Czecho-Slovakia	896	1775	23,000
31	Battersea, England	850	600	160,000
32	Antwerp, Belgium	850	550	60,000
33	Barking, England	800	600	70,000
35	Tir John North, England	850	650	60,000
35	Brimsdown, England	940	1900	50,000

TABLE 3. FEDERAL SHIPS OF 400 LBS. AND 750 DEG.

1. SHIPS			
Design	A	B	C
Year	30	32	35
Number of ships	2	4	2
Owner	Std. Ship. Co.	Panama Mail Line	Std. Ship. Co.
Name of Ships	(a)	(b)	(c)
2. CONDITIONS			
Shaft Horsepower	4000	12000	3000
Steam pressure, lbs. gauge (d)	400	400	400
Steam temp., deg. F. (d)	750	750	750
3. FUEL CONSUMPTION			
Fuel rate, lbs./SHP (e)	.597	.612	.577
Heat consumption, BTU/SHP	11,340	11,630	10,960
Thermal efficiency, %	22.5	21.9	23.2

a. G. Harrison Smith and W.S. Farish.
b. Santa Rosa, Santa Paula, Santa Lucia, Santa Elena.
c. R. P. Resor and T. C. McCobb.
d. At superheater outlet.
e. For all purposes. Based on oil of 19,000 BTU per lb.

TABLE 4. MARINE INSTALLATIONS OF 700 - 799 DEG.

YEAR	SHIP OR CLASS	NATION-ALITY	NO.OF SHIPS	STM.TEMP. DEG.F.	STM.PRESS. LBS. GA.	S.H.P.	APPROX.FUEL RATE LB/SHP(a)
26	King George V	British	1	700	545	3,600	.79(b)
27	Carl D.Bradley	U.S.	1	700	325	4,800	.81(b)
29	Viceroy of India(c)	British	1	750	400	17,000	.653
30	G.Harrison Smith(d)	U.S.	2	750	400	4,000	.596
30	Empress of Japan(e)	British	1	700	375	30,000	.595
30	Hansa (f)	German	4	715	400	28,000	.76
31	Virginia Sinclair	U.S.	2	700	400	4,500	.66
31	Antigua (c)	U.S.	6	700	350	10,500	(.67)
31	Empress of Britain(e)	British	1	700	425	60,000	.57
31	Carthage	British	2	700	400	15,000	(.65)
31	Strathnaver (c)	British	2	725	425	28,000	.595
31	Acheron (h)	British	1	720	500	34,000	.60
32	Seatrains	U.S.	2	700	400	8,000	(.65)
32	Santa Rosa (d)	U.S.	4	750	400	12,000	.613
33	El Mansour	French	1	707	---	12,000	(.68)
35	Kertosone (g)	Dutch	1	708	682	5,800	(.70)
35	Orion	British	1	725	425	24,000	(.63)
35	Strathmore	British	1	725	440	24,000	(.63)

a. For all purposes. Based on oil of 19,000 BTU per lb. Values in parentheses are less accurate than others.
b. Ship is coal burning. Rate is converted to equivalent oil.
c. Turbo electric.
d. Fitted with attached generator and electric auxiliaries.
e. Diesel generators and electric auxiliaries.
f. Formerly "Albert Ballin".
g. High pressure turbine superimposed on existing plant.
h. Destroyer.

TABLE 5. MARINE INSTALLATIONS OF 800 DEG. AND ABOVE

YEAR	SHIP OR CLASS	NATION-ALITY	NO.OF SHIPS	STM.TEMP. DEG.F.	STM.PRESS. LBS. GA.	S.H.P.	APPROX. FUEL RATE LBS/SHP(a)
30	Uckermark (b)	German	1	824	850	6,000	.62
31	Revenue Cutters(c)	German	-	850	640	1,600	.76
35	Gneisenau (d)	German	2	880	711	26,000	.58
35	Potsdam (d)	German	1	900	1320	26,000	.55
35	U.S. Liner (e)	U.S.	1	850	600	40,000	.56
35	Proposed ship (f)	---	-	950	1200	8,000	.47

a. For all purposes. Based on oil of 19,000 BTU per lb.
b. Conversion of main turbine, using old steam auxiliaries.
c. Steam auxiliaries.
d. Turbo-electric drive, with electric auxiliaries.
e. Proposed, with electric auxiliaries.
f. Electric auxiliaries, and generator attached to main turbine.
See also Table 6.

construction and operation are well developed and practically standardized. It is generally known that they operate satisfactorily, and that they are more economical than those of lower temperature. This is especially true of the Federal ships with 750 degrees temperature. Thus, for such installations, the adverse comments in the paper are generally disproved.

For temperatures above 800 degrees there are a few marine installations, as given in Table 5. All of them were made in Germany, which is leading in this respect. Of particular importance are the large installations on the *Gneisenau* and *Scharnhorst* with 700 pounds pressure and 880 degrees temperature; and on the *Potsdam* with 1320 pounds pressure and 900 degrees temperature. While the fuel consumptions of these ships are low, they would be still lower with high-speed geared-turbines instead of turbo-electric drive. The information available indicates that these installations operate satisfactorily, and are superior to those of lower temperature.

For naval machinery, specific data are not available. In this country temperatures have reached 700 degrees; and abroad it is rumored that they are higher.

From the foregoing it is clear that the trend is to higher temperatures. Evidently high-temperature machinery operates satisfactorily and results in substantial gain. It is indicated that the best practice and the best economy for future machinery will be with temperatures between 900 and 1000 degrees.

MERCHANT SHIPS.

With respect to merchant ships, it is implied that the economic advantages are relatively small compared with low temperatures, and particularly with saturated steam at 300 pounds pressure. A comparison on an equal basis of a machinery installation for the latter condition with others for high temperatures is given in Table 6. All installations have boilers, turbines and auxil-

TABLE 6. PROPOSED AND MODERN STEAM CONDITIONS FOR MERCHANT SHIPS

Number of screws---------- 1
Shaft horsepower---------- 8000
Boiler efficiency %-------- 87.5
Vacuum, inches mercury----- 28.5

1. CONDITIONS.			
Design	A	B	C
Steam pressure, lbs. gauge	300	400	1,200
Steam temp.,deg. F.	422	750	950
2. FUEL CONSUMPTION.			
Fuel rate, lbs.per SHP (a)	.77	.58	.47
Heat consumption, BTU per SHP.	14,640	11,000	8,930
Thermal efficiency, %	17.4	23.2	28.3
3. WEIGHT AND COST			
Weight, lbs. per SHP	256	215	180
Cost, dollars per SHP	117	107	103
4. RATIO TO "A"			
Fuel Consumption	1.00	.75	.61
Weight	1.00	.84	.70
Cost	1.00	.91	.88

a. For all purposes. Based on oil of 19,000 BTU per lb.

TABLE 7. PROPOSED AND MODERN CONDITIONS FOR NAVAL SHIPS

Number of screws---------- 2
Shaft horsepower, Total---50,000
Boiler efficiency,%(a)---- 82.5
Vacuum, inches mercury(a)- 27.5

1. CONDITIONS.			
Design	A	B	C
Steam pressure, lbs.gauge	300	400	1200
Steam temperature,deg.F.	422	750	950
2. FUEL AND WEIGHT.			
Fuel rate, lbs. per SHP(b)	.874	.658	.533
Weight, lbs. per SHP	30.5	26.4	24.0
3. RATIO TO "A".			
Fuel consumption	1.00	.75	.61
Weight	1.00	.87	.79

a. At designed power.
b. For all purposes. Based on oil of 19,000 BTU per lb.

iaries of the same type and design. To obtain reliability and high efficiency, particularly with the high temperatures, high-speed turbines are used. The values were carefully estimated from reliable data, and are considered relatively accurate.

The paper implies that the reduction in fuel consumption would not be over 14 per cent. However, it is seen from the table that the savings are 25 and 39 per cent respectively, and are therefore much greater.

It may be inferred from the paper that the reduction in fuel consumption due to high temperature would not be over 17 per cent. However, on an equal basis, it may be much greater as seen from Tables 6 and 7. The implied inferiority of high temperatures at low powers is misleading. When necessary, such installations can be designed to give fuel consumptions at low powers which are very much lower than for low temperatures, and savings being of about the same order as given in Tables 6 and 7.

It is implied that the weight and space are greater for high temperatures. However, it is seen from Table 6 that the weight is considerably less, which is also true of the space. Also, the cost is somewhat less. These characteristics are substantiated by a number of designs and estimates. Therefore, in these respects, high temperatures are advantageous.

Relative to low temperature ships, the Federal high-temperature ships have been especially reliable, the delays have been very small, and the cost of repairs and upkeep has been low. The implication of extensive grooming every time a ship enters a home port is inaccurate and misleading. In case of operation and maintenance, they are quite equal to low-temperature ships. The foregoing is generally true of the ships between 700 and 800 degrees.

Rugged simplicity was characteristic of automobiles twenty-five years ago. Today, they are more complicated, but better. The same is true of ships. The real measure is general excellence, rather than simplicity alone. High-temperature machinery is not so complex, as indicated by the weight and space. Altogether it is better, and therefore desirable.

With respect to the difficulties and delays in construction and repairs; there is not much difference, if any. The important thing is the first cost, which is less.

DESIGN	A	B	C
Steam pressure,lbs.gauge	300	400	1200
Steam temperature, deg.F.	422	750	950
Velocity, ft. per second	150	160	170
Pipe size, inches	7	6	3½
Thickness, inches	.278	.322	.365
Joints	Flanged	Flanged	Welded
Total weight, lbs. (a)	4760	5350	4175

(a) Total main steam system from boiler outlet to turbine inlet. Includes throttle and nozzle manifolds.

TABLE 8.—MAIN STEAM PIPING.

Shaft Horsepower 8000, Pressure Drops from boiler outlet to turbine inlet in per cent.—6.

High pressure piping is very much smaller, as shown in Table 8. It is seen that the high pressure pipes of design C are half the size of the low pressure ones. While the high pressure bends are larger in proportion, they are actually about the same size. For the pipes and insulation, the space is

about the same. With proper insulation, the surface temperatures are approximately the same, and therefore, the spaces are no hotter with high temperatures.

When properly operated, high pressure boilers are equally as reliable as low pressure ones, as has been amply proved in many ships and power plants. The conditions are more exacting, but they are easy to maintain, if the machinery is designed properly.

With respect to maneuvering, the Federal ships have been quite satisfactory, and fully equal to those of low temperature. The turbines are no more sluggish, nor do they require a longer time to change speed. The astern turbines operate equally as well, and the exhaust temperatures have not been excessive or dangerous. Furthermore, these ships do a great deal more maneuvering than naval ships, and quite frequently at full power.

For many years marine practice has been trailing land practice with a lag of about five years. The present practice and future trend of power plants are therefore important as indicating what may be expected in future marine installations. In general, it is indicated that temperatures between 900 and 1000 degrees will be more profitable than lower temperatures.

Since it is important for American ships to operate at low cost, owners should take advantage of the large economic savings which can be effected. It is believed they will do so, and that higher temperatures will be used.

NAVAL SHIPS.

I do not agree with the view that high temperatures are not suitable for naval vessels. It is my opinion that they are, and that their use will considerably enhance the fighting qualities of naval ships.

A comparison on an equal basis between a machinery installation for low temperature, as advocated in the paper, and others for high temperature is given in Table 7. All installations have boilers, turbines, and auxiliaries of the same type and design. To obtain reliability and high efficiency, particularly with high temperatures, high-speed main and cruising turbines are used. The values were carefully estimated and are considered relatively accurate.

It is implied that the reduction in fuel consumption at full power will not be over 10 to 15 per cent. However, the table shows that the reductions are 25 and 39 per cent respectively and are therefore much greater.

It is implied that the reduction at cruising speed will not be over 6 per cent. However, the reductions would be of about the same order as given in the tables, and therefore much greater.

It is implied that the weight and space of high-temperature machinery are greater. However, the table shows that the weight is considerably less, which is also true of the space. Therefore, in both respects, high temperature is advantageous.

With respect to the various disadvantages given, the foregoing comments on merchant ships also apply generally to naval ships. The reliability of high temperature machinery, and its ability to keep the sea without extensive grooming are considered quite equal to the low-temperature type. In fact, it can keep the sea longer with a given quantity of fuel, because of its lower fuel consumption.

It is considered that properly designed high-temperature machinery will be no more sluggish than the low-temperature type, and that it will maneuver equally as well. For maneuvering, full flow of circulating water should be provided. The astern turbines should then operate equally as well as in merchant ships, where their performance has been quite satisfactory, and without excessive exhaust temperatures. It is believed that the astern

turbines will operate satisfactorily, and quite as well as the low-temperature type.

For many years, Navy practice has been trailing merchant practice with a lag of about five years. Since merchant practice lags about five years behind land practice, Navy practice is about ten years behind the latter. Therefore, the present practice and future trend in power plants and merchant ships may be expected to indicate the future of Navy practice.

The facts in Tables 1 to 5 lead to the inevitable conclusion that higher pressure and temperatures will be used. In this respect, the steamer *Potsdam* with 1320 pounds pressure and 900 degrees temperature is of especial importance.

Naval machinery which is good for 850 degrees temperature is now being built. It should be easy to operate one ship at this temperature, and it is hoped that this will be done. If so, it is believed that the superior performance would lead to operating all of these ships at this temperature.

Considering the great number of Naval vessels, and the high importance of major improvements, research and development are fully justified. The Government has enormous resources, and can well afford the relatively small expense which would be required. The Navy should not be held back by the slow process of service development. Naval machinery should not be behind, but should be in advance, as it used to be.

It is believed that the Government and the Navy should help materially in developing more economical machinery for merchant ships. At present, this is not being done.

In view of the foregoing, it would be worth while for the Navy to make an experimental installation of the highest temperature now possible, which is 1000 degrees or more. The results of such a development may be great in importance, and far-reaching in effect; both for naval and merchant ships.

Finally, I believe that both merchant and naval machinery will progress to higher pressures and temperatures; and, that better machinery and ships will result.

I wish to congratulate the Author on bringing out for discussion many valuable points.—Marine Journal, 15 December, 1935.

CONTROL OF SUPERHEAT.*

By Thomas B. Stillman, Engineering Department, Babcock & Wilcox Company.

The fundamental reason for controlling superheat is to provide steam temperatures at the turbines which are most suitable for their efficient operation over a relatively wide range of rating of the boilers. On shipboard, in addition to the above reason, another of almost equal importance in modern high temperature installations is to insure proper steam temperatures under maneuvering conditions, so that possible damage to the propelling machinery and condensers will not occur. Also, in a marine installation, the steam requirements in port are radically different from those underway, requiring control of the superheat to meet these special conditions properly.

Aside from the effect change of boiler rating has upon superheat, there are a number of other factors in connection with boiler and furnace operation

* This paper was read before the Society of Naval Architects and Marine Engineers, November 14, 1935.

that affect superheat, and before proceeding to methods of control it might be well to review some of these factors and clearly understand their relation to the problem.

FEED-WATER TEMPERATURE.

Increasing the feed-water temperature to a boiler decreases the superheat for a given rating. This is because an increase in feed-water temperature increases the steam flow through a superheater, with no corresponding change in the gas flow over the superheater. Figure 1 indicates the general trend of the effect of feed-water temperature on superheat. For the particular steam conditions on which this curve is based, it may be noted that a 10-degree F. change in feed-water temperature will cause a change of approximately 1 per cent in superheat.

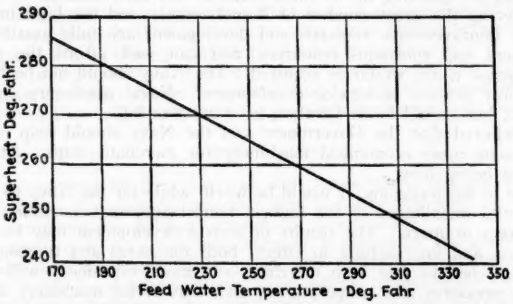


FIGURE 1.—CURVE SHOWING TYPICAL CHANGE IN SUPERHEAT CAUSED BY CHANGE IN TEMPERATURE OF FEED WATER TO BOILER.

SATURATED BY-PASS STEAM.

A number of the auxiliaries as well as the heating load usually require saturated steam. If this steam is taken directly from the boiler drum, the steam so taken by-passes the superheater, and the remaining steam absorbs more heat per pound than if all the steam generated by the boiler went through the superheater. Figure 2 indicates the approximate result upon the superheat that may be anticipated by by-passing different percentages of saturated steam. From this curve it may be noted that by-passing 15 per cent of the steam increases the superheat about 15 per cent. By-passing 55 per cent of the steam approximately doubles the superheat.

It is because of this radical effect that by-passing of steam has upon the temperature of the remaining steam coming from the superheater under maneuvering conditions that desuperheaters for auxiliary steam have come into quite general use aboard modern steamships. In this way, all of the steam generated by the boiler is allowed to pass through the superheater at all times, the auxiliary steam then being desuperheated as required.

EXCESS AIR IN PRODUCTS OF COMBUSTION.

The greater the excess air in the products of combustion of a given fuel, the higher the superheat, unless the superheater is of the strictly radiant type. This is caused by the fact that as excess air is increased the temperature of

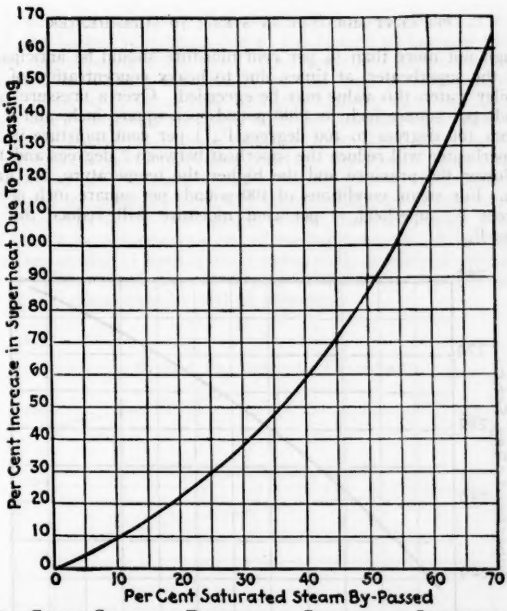


FIGURE 2.—CURVE SHOWING PERCENTAGE CHANGE IN SUPERHEAT DUE TO BY-PASSING VARIOUS PERCENTAGES OF SATURATED STEAM.

the furnace gases is reduced, but the temperature of the gases passing through the tube bank is not further reduced as much as it would be with lower excess air. This results in actually higher temperature of gases leaving the boiler with high excess air than would exist with low excess air at the same rate of combustion.

This higher gas temperature is largely due to the increased gas weight and higher velocity due to the excess air, which will cause an increase in the superheat over that obtained with lower excess air from a superheater located in the boiler tube bank. The farther back from the furnace the superheater is located, the greater the effect of a change in excess air.

Figure 3 indicates the change in superheat that may be expected at a given rate of fuel-oil burning, due to variations in excess air, with an interdeck superheater located approximately 15 per cent of the boiler heating surface up from the furnace. As may be noted from this curve, a change in excess air from 12 per cent (14 per cent CO_2) to 28 per cent (12 per cent CO_2) increases the superheat approximately 7 per cent. With a superheater located at the top of the first and second passes of a header-type boiler, where the gases pass over approximately 40 per cent of the boiler heating surface before reaching the superheater, the percentage increase in superheat will be approximately 15 per cent for an increase in excess air of from 12 per cent to 28 per cent. With a superheater located one or two boiler tubes above the furnace, practically no change in superheat may be anticipated over a relatively wide range of excess air.

PER CENT MOISTURE IN STEAM TO SUPERHEATER.

Although not more than ¼ per cent moisture should be anticipated in the steam to the superheater, at times, due to heavy concentration of impurities in the boiler water, this value may be exceeded. Over a pressure range from 200 pounds per square inch to 1200 pounds per square inch, and a superheat range from 100 degrees to 400 degrees F., 1 per cent moisture in the steam to the superheater will reduce the superheat between 7 degrees and 16 degrees F.; the lower the pressure and the higher the temperature, the greater the reduction. For steam conditions of 400 pounds per square inch pressure and 250 degrees F. superheat, 1 per cent moisture will reduce the superheat 14 degrees F.

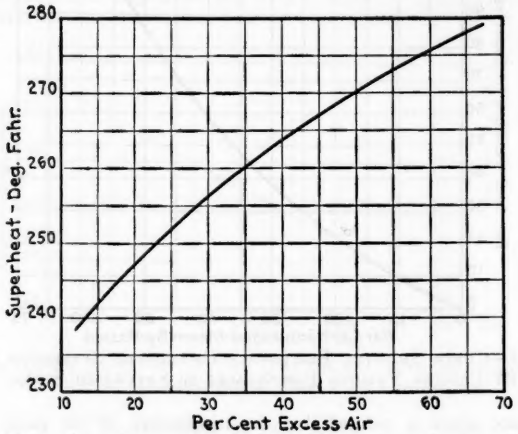


FIGURE 3.—CURVE SHOWING TYPICAL EFFECT UPON SUPERHEAT OF CHANGING THE PERCENTAGE EXCESS AIR IN PRODUCTS OF COMBUSTION (SUPERHEATER IN INTERDECK POSITION).

LOCATION OF SUPERHEATERS IN BOILER.

The percentage of boiler surface between the superheater and furnace is an important factor in the slope of a superheat-rating curve. A convection-type superheater well removed from the furnace will show a rapid percentage increase in superheat with rating. As the superheater is moved nearer the furnace the superheat-rating curve tends to flatten, and it is possible to locate a superheater so that it will have a flat superheat curve over a wide range of rating. A radiant-type superheater located in the furnace walls will give decreasing superheat with increase in rating. By combining a radiant-type superheater with a convection-type in the same boiler, a comparatively flat superheat curve may be obtained.

This is illustrated in Figure 4 where the decreasing superheat with increased rating of a radiant-type superheater, combined with the increasing superheat with increased rating of a convection-type superheater, produces a comparatively flat superheat curve. Because of the relatively small furnaces

available in marine installations, however, radiant-type superheaters are not feasible for the higher superheats due to the hazard of burning them, especially under maneuvering conditions. Also the complication and weight of piping involved in using a superheater of this type in combination with a superheater of the convection type militates against their use aboard ship.

Although single superheaters have been so installed in boilers that flat superheat-rating curves have been obtained from them, this has been only where steady load conditions existed and the superheater was not exposed to the hazards incident to sudden load changes. Due to its proximity to the furnace, the gas temperatures normally surrounding such a superheater, combined with the velocity of these gases, render their use under maneuvering conditions almost as hazardous as one of the radiant type. Accordingly, with our present knowledge of metals, the commercially feasible procedure aboard ship is to have the superheater so located in the boiler that a rising superheat with rating characteristics will be obtained.

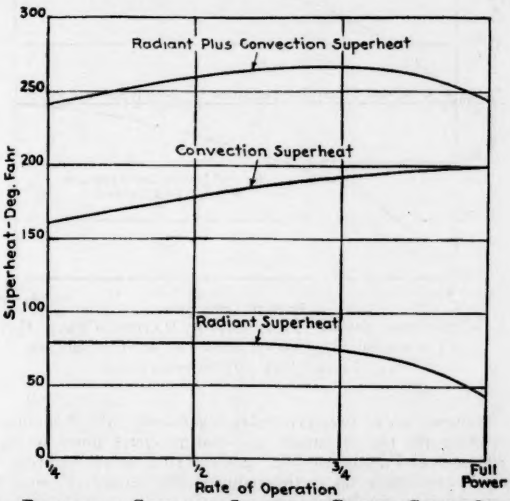


FIGURE 4.—RELATIVELY CONSTANT SUPERHEAT-RATING CURVE OBTAINED BY COMBINING THE CHARACTERISTICS OF A RADIANT TYPE AND CONVECTION TYPE SUPERHEATER.

From the preceding it will be realized that, as higher steam temperatures are employed and less margin is left for the designer to work to, some form of superheat control becomes essential, not only to assure a relatively flat super-heat-rating curve, but also to take care of the possible variations in super-heat that may occur due to the operator's procedure in handling the boilers. The superheat cannot be allowed to go too low over a wide range of operating conditions or the plant efficiency will suffer, and also it cannot be allowed to exceed the designed maximum greatly without introducing the hazard of damaging the propelling machinery and condenser, or burning a portion of the superheater.

METHODS OF CONTROLLING SUPERHEAT.

Fundamentally, there are two principles generally employed for controlling superheat: (1) Providing an excess of superheating surface so as to give the desired steam temperature at low rates, with provision for cooling the steam at the higher rates, and (2) controlling the flow of gases over the superheater so that the steam temperature always remains within certain limits regardless of the rating of the boiler.

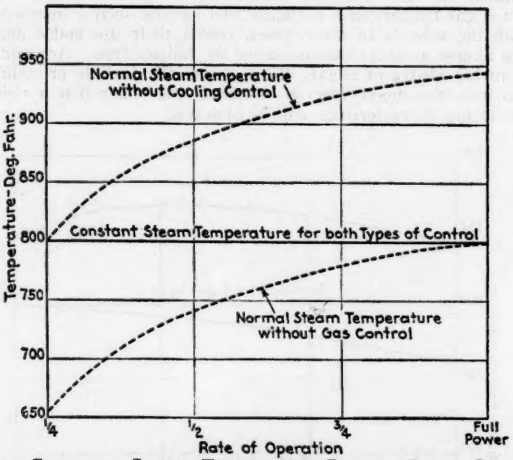


FIGURE 5.—CONSTANT STEAM TEMPERATURE-RATING CURVE OBTAINED BY (A) COOLING THE STEAM AND (B) BY CONTROL OF GAS FLOW OVER THE SUPERHEATER.

Figure 5 shows these two principles graphically, the "cooling control" serving to bring the normal steam temperature curve down to the constant value of 800 degrees F., whereas the "gas control" serves to bring its normal steam temperature curve up to the required 800 degrees F. over the entire range of operation of the boiler.

In comparing these two systems it is also important to remember that the "cooling control" has no measurable effect upon the efficiency of the boiler unit, whereas the "gas control" has, as will be explained later.

CONTROL OF SUPERHEAT BY COOLING.

The cooling type of control may be divided into (*a*) those injecting water into the steam and (*b*) those cooling the steam in a heat exchanger by conducting the excess heat to the feed water or the boiler circuit: (*a*) may again be divided into (1) spray-type desuperheaters and (2) those employing surface evaporation, where water is allowed to trickle over wires or metal surfaces exposed to the superheated steam, the water being evaporated and picked up by the steam as it flows past.

SPRAY TYPE OF DESUPERHEATER.

The spray-type desuperheaters are relatively simple and compact, but to obtain consistently satisfactory results with them the water should be finely atomized and a reasonable length of travel allowed the steam beyond the spray before its utilization in a turbine to insure complete evaporation of the water and thorough mixing of the steam. Suitable automatic thermal control should be provided to govern the amount of spray water, the thermal element being located some distance down the pipe to assure properly mixed steam for actuating the control. Such a set-up of necessity introduces a considerable lag in the functioning of the desuperheater, so that, except when the flow of steam is relatively constant, difficulty may be experienced in avoiding momentary water carry-over or excessive steam temperatures.

With spray-type desuperheaters it is also essential that the spray water used be of exceptional purity, if difficulty is to be avoided further along in the circuit with impurities in the steam. If the spray water is not of excellent quality, conditions similar to those resulting from excessive priming in a boiler may be anticipated.

SURFACE EVAPORATION TYPE OF DESUPERHEATER.

The surface evaporation type of desuperheater largely eliminates the carry-over of solids from the water to the steam, the majority of these being left on the wires, but the control picture, from the point of view of momentary water carry-over or excessive steam temperature under conditions of varying steam flow, is similar in both types.

In Publication No. A2, issued in August, 1933, by the Edison Electric Institute, a number of statements by users of desuperheaters in the power plant field are given, most of these desuperheaters being used to reduce the temperature of steam which has been generated in modern high-pressure and high-temperature boilers so that it may be used in the older turbine units. It is interesting to note that one of the most successful installations reported utilized a steam atomizer for discharging the water into the steam line, this providing excellent atomization of the water, with consequent ease of absorption by the steam, over a wide range of operating rates.

CONVECTION TYPE OF DESUPERHEATER.

The convection type of desuperheater eliminates the possibility of contamination of the steam with impurities from the cooling water, as the two are never allowed to mix. As previously indicated, either feed water or water from the boiler may be used for the cooling medium. Feed water permits the use of a smaller unit due to the better thermal head available, but the boiler water installation is the simpler from an operating point of view and will not cause fluctuations in the feed-water temperature as it enters the boiler.

Figure 6 illustrates the construction and principle of operation of one of these units. The thermally actuated butterfly valve in the steam line serves to control the percentage of steam diverted to flow through the cooling tubes, which are surrounded with water. By varying the percentage of steam so diverted, any desired range in superheat may be obtained, and at no time will there be danger of water in the steam if the cooling water is taken from the boiler circuit.

Figure 7 illustrates the application of one of these units to a modern high-pressure, high-temperature stationary boiler unit. It may be noted that the desuperheater is located in the steam flow approximately half way through

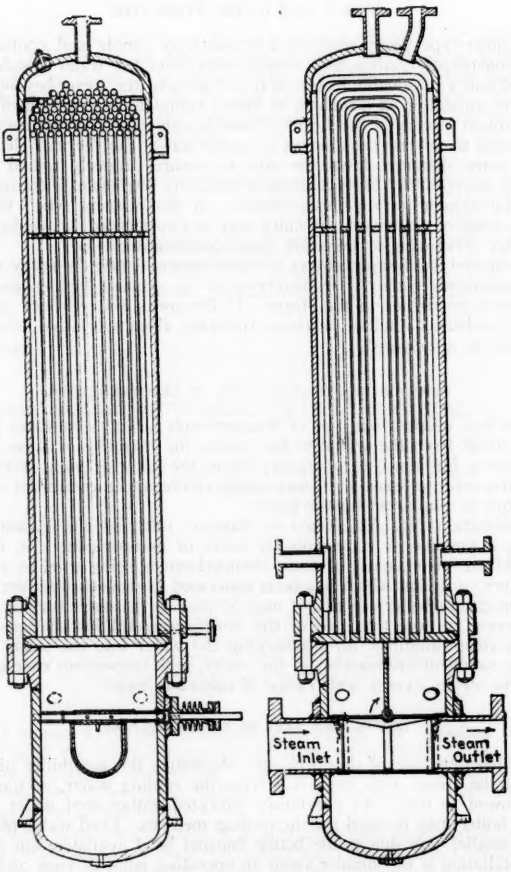


FIGURE 6.—A CONVECTION TYPE OF DESUPERHEATER.

the superheater, with the thermostat actuating the butterfly valve placed at the final superheater outlet. This serves two purposes; it keeps the final steam temperature at the superheater outlet at the maximum point required by the turbine with corresponding protection to the superheater tubes, and it also provides a thorough mixing of the steam for dependable thermostatic control without the necessity of moving the thermostat some distance from the boiler unit.

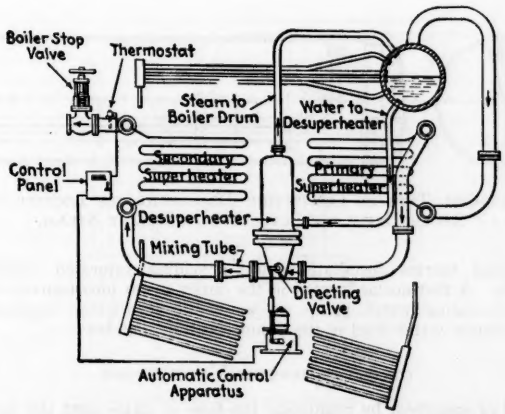


FIGURE 7.—APPLICATION OF A CONVECTION TYPE OF DESUPERHEATER TO HIGH-TEMPERATURE STATIONARY BOILER UNIT.

Desuperheaters having the cooling water mix with the steam could be located in a similar position and theoretically provide the same protection to the superheater tubes in the last passes, but actually, between the possibility of water carry-over, momentary lack of desuperheating, and deposit of solids in this critical portion of the superheater, such an installation would be more liable to increase the hazard to which these last pass superheater tubes are exposed, than if the desuperheater were installed at the superheater outlet.

DESUPERHEATERS FOR AUXILIARY STEAM.

For providing auxiliary steam, the almost universal practice afloat today, in the higher temperature installations, is to desuperheat a portion of the steam which has been through the superheaters. This may be done with either the convection or injection type of desuperheater. However, it is to be kept in mind that, if proper control of the gas flow over the superheater is provided in the boiler unit, such desuperheaters will be unnecessary and saturated steam for auxiliary purposes may be taken directly from the boiler drum without introducing any hazard to the superheater because of this steam by-passing the superheater under maneuvering conditions.

If auxiliary desuperheaters are necessary, unquestionably the simplest and lightest weight type is a coil of pipe located below the water level in the steam drum. This lessens accessibility in the drum, and also leaves the steam with some superheat in it (from 25 to 50 degrees F.), but there are no moving parts and nothing requiring periodic attention. Figure 8 shows a desuperheater of this type, designed to handle up to 10,000 pounds of steam per hour from 252 degrees F. superheat to 30 degrees F. superheat, located in the steam drum of a header-type boiler.

The spray and surface evaporation types of desuperheaters are more liable to fluctuations in superheat, especially if the primary steam temperature is relatively high; but, on the average, an auxiliary load is fairly steady, which is an important factor in the successful performance of such an installation. Figure 9 shows a spray-type desuperheater which has found wide application

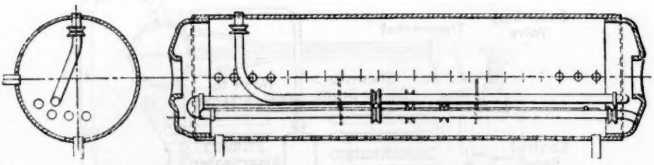


FIGURE 8.—COIL TYPE OF CONVECTION DESUPERHEATER LOCATED IN BOILER STEAM DRUM FOR SUPPLYING AUXILIARY STEAM.

in European marine installations for providing saturated steam to the auxiliaries. A thermostat located in the outlet steam pipe controls the speed of the circulating water pump, an automatic feed-water regulator maintaining constant water level in the desuperheating chamber.

CONTROL OF SUPERHEAT BY GAS FLOW.

Control of superheat by regulating the flow of gases over the superheater is accomplished in two general ways: (1) By means of dampers, and (2) with separately fired superheaters.

DAMPERS.

When dampers are used for controlling superheat, they may be located somewhere in the boiler, but usually, for marine service, it has been customary to place them in the uptake. If a damper is located in a boiler, it should be placed far enough from the furnace to prevent the possibility of its overheating and warping at the designed maximum rates of operation. The use of heat-resisting alloys for this purpose will be a good investment in some cases. Also, if the quantity of gas to be controlled is relatively large, it will usually be desirable to install a number of small damper units rather than one large damper. This will appreciably reduce the warping hazard.

Regardless of where they are located, the use of dampers inherently introduces a condition of unbalanced gas distribution through the boiler unit, and in designing units so fitted care should be exercised to avoid the possibility of any damage occuring due to local concentration of hot gases on any portion of the heating surfaces, regardless of damper opening or rating of the boiler. For example, if a unit is designed to give the desired superheat under full power conditions with the damper or dampers in the open position, closing the dampers so as to divert practically all of the gases through the superheater may result in damage to that portion of the unit. To reduce this hazard, dampers are frequently installed so that they can close off only a certain percentage of the free gas flow area surrounding them, the partial control thus provided usually being sufficient to meet the normal operating requirements from a superheat control point of view.

When raising steam in modern high-temperature boilers, care must always be used to avoid overheating the superheater unit. Restricting the flow of gases over the superheater at this time by means of a damper will reduce the possibility of such overheating and will also make it possible to place the boiler on the line faster than would be the case if the damper were not used.

In controlling superheat by means of gas flow, it is of course essential that the superheating surface be localized so that the desired control will be obtained. In marine service, where damper control has been applied to A-

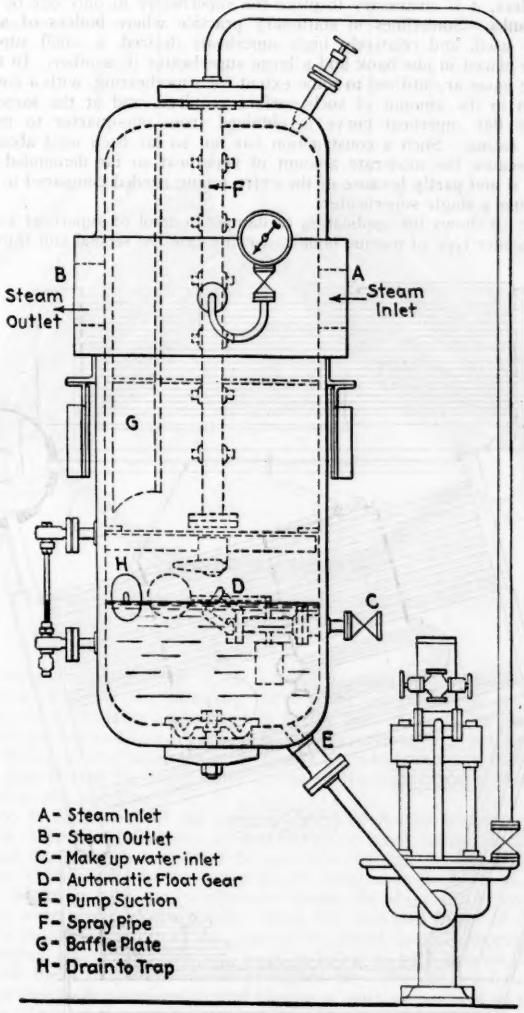


FIGURE 9.—SPRAY-TYPE DESUPERHEATER FOR SUPPLYING AUXILIARY STEAM.

type boilers, it is customary to place the superheater in only one of the two boiler banks. Sometimes in stationary practice where boilers of a similar type are used, and relatively high superheats desired, a small superheater has been placed in one bank and a large superheater in another. In this way all of the gases are utilized to some extent for superheating, with a consequent reduction in the amount of such surface required, and at the same time a relatively flat superheat curve is obtained from one-quarter to maximum capacity rating. Such a construction has not so far been used aboard ship, partly because the moderate amount of superheat so far demanded has not required it and partly because of the extra piping needed compared to a boiler unit having a single superheater.

Figure 10 shows the application of damper control of superheat to a well-known header type of marine boiler. In this case the second and third passes

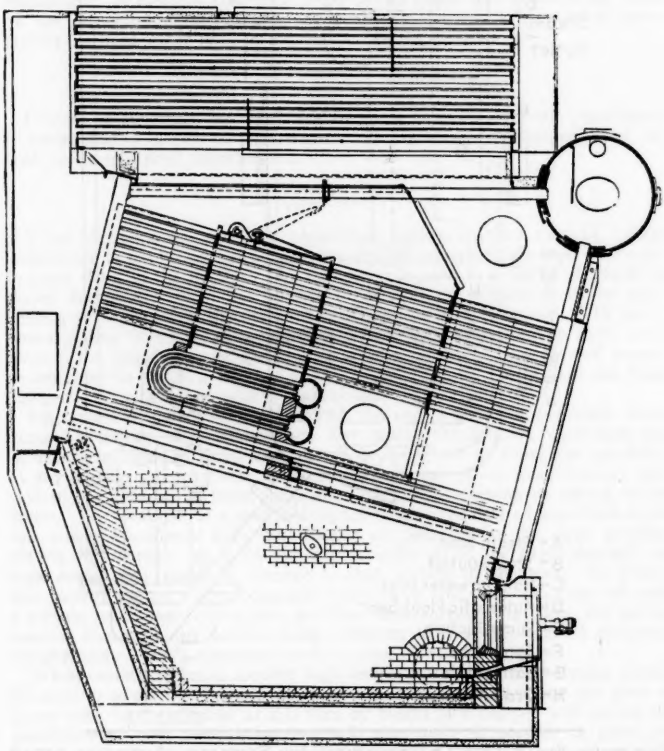


FIGURE 10.—HEADER-TYPE MARINE BOILER FITTED WITH DAMPER FOR CONTROLLING SUPERHEAT.

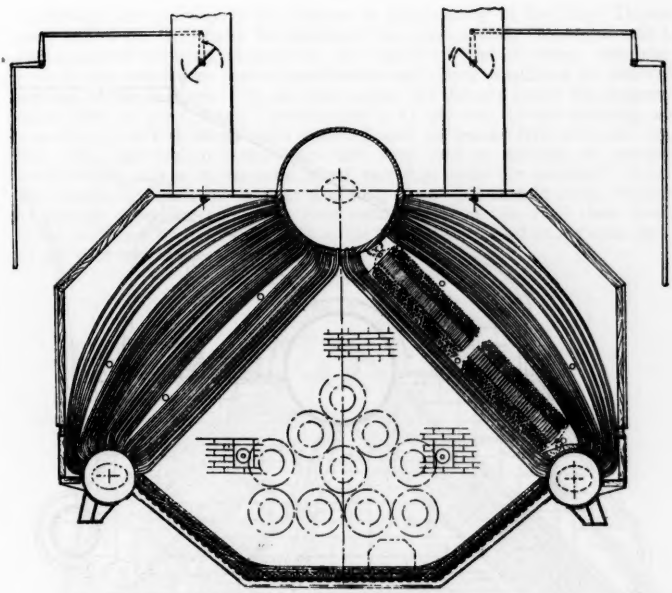


FIGURE 11.—A-TYPE MARINE BOILER FITTED WITH DAMPERS FOR CONTROLLING SUPERHEAT.

of the boiler are swept by all of the gases regardless of the damper opening, assuring a relatively flat efficiency curve under all conditions of operation. This feature of utilizing approximately 50 per cent of the boiler heating surface with the full gas flow regardless of damper opening does not apply to the A-type boiler as may be noted from Figure 11, which shows a marine boiler of this type having the superheater in one of the boiler banks, with suitable dampers in the uptakes.

Figure 12 shows one of the damper-controlled A-type boilers installed in the S. S. *Empress of Britain*. In this case, one large damper located above the steam drum serves to control the gas flow through the two boiler banks.

Figure 13 shows one of the larger boilers installed in the U. S. S. *Farragut* type of destroyer. In the installations aboard the ships 49 per cent closure dampers were placed in the uptakes above the saturated banks of the boilers only, but in the test boiler of this type at the Naval Boiler Laboratory in the Philadelphia Navy Yard dampers were installed in both uptakes in accordance with the arrangement shown in Figure 13. The damper located above the saturated bank permitted a total closing of only 49 per cent of the uptake area, to eliminate the possibility of damage to the superheater due to excessive restriction of the uptake on this side, whereas the damper above the superheater, when closed, stopped all flow of gas through that side of the boiler.

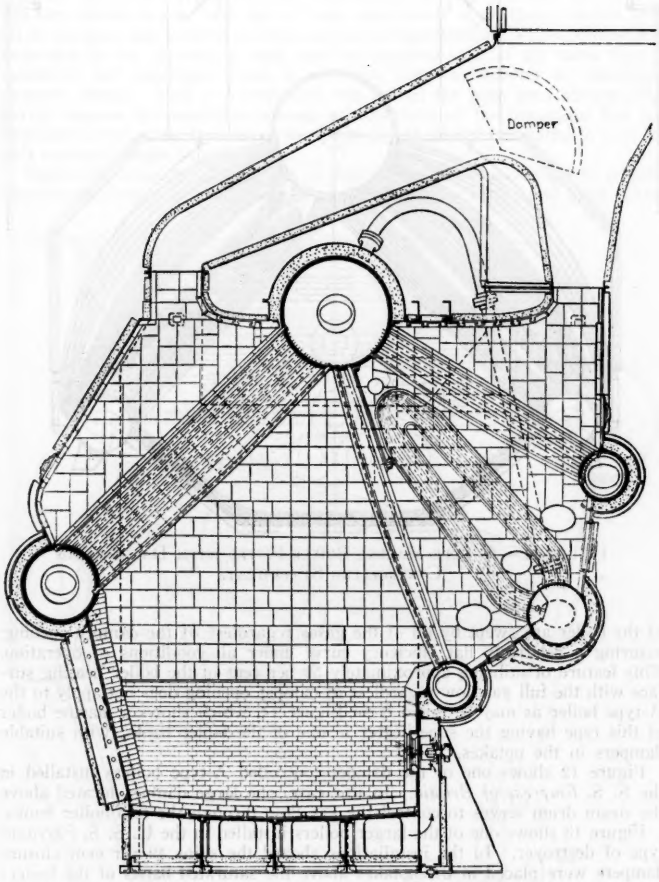


FIGURE 12.—A-TYPE BOILER IN S. S. "EMPRESS OF BRITAIN" FITTED WITH DAMPER FOR CONTROLLING SUPERHEAT.

Through the courtesy of the Bureau of Engineering of the Navy Department and of the Bethlehem Shipbuilding Corporation, Ltd., Figures 14 and 15 are presented showing respectively the superheat and efficiency characteristics of this unit under various combustion and rating conditions for different settings of the dampers. As has been noted, the damper above the saturated bank when in the "closed" position left a 51 per cent uptake opening, and accordingly no test points were obtained with an uptake free area less than this. For that reason dotted lines have been used to indicate the probable trend of the curves in the zone where test data were not obtained. Above the superheater bank the damper was fully closed for certain tests, resulting in definite superheat points for zero uptake area on this side, these points being connected by light solid lines to the heavier lines used in the zone above 51 per cent free uptake area.

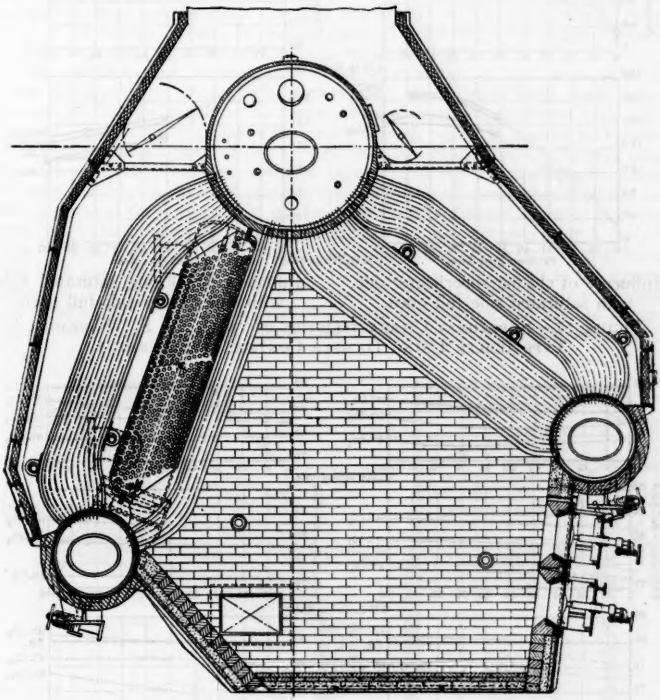
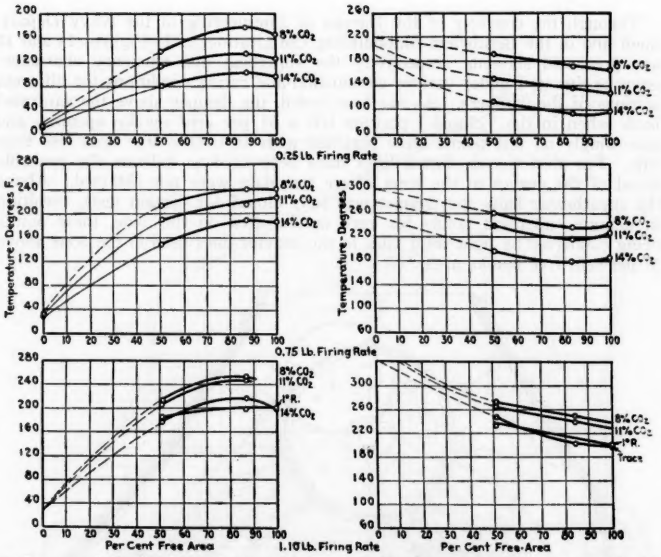


FIGURE 13.—U. S. S. "FARRAGUT" TYPE OF BOILER AT NAVAL BOILER LABORATORY FITTED WITH DAMPERS FOR CONTROLLING SUPERHEAT.

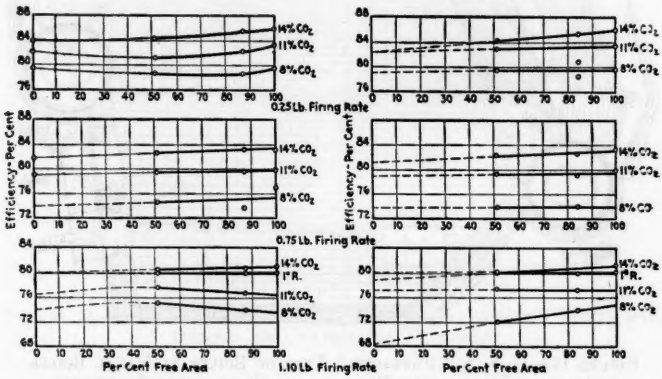
From these curves it may be noted that when the boiler was operating at the 0.75 pound of oil per square foot of boiler heating surface rate use of the dampers made it possible to vary the superheat from 200 degrees F. (saturated



Influence of closing superheater side with saturated side full open.

Influence of closing saturated side with superheater side full open.

FIGURE 14.—SUPERHEAT CHARACTERISTICS OF THE U. S. S. "FARRAGUT" TYPE BOILER USING DAMPER CONTROL OF SUPERHEAT.



Influence of closing superheater side with saturated side full open.

Influence of closing saturated side with superheater side full open.

FIGURE 15.—EFFICIENCY CHARACTERISTICS OF THE U. S. S. "FARRAGUT" TYPE BOILER USING DAMPER CONTROL OF SUPERHEAT.

uptake 51 per cent open) to 30 degrees F. (damper in uptake over superheater closed), when the CO_2 in the uptake gases was 14 per cent (12 per cent excess air).

Figure 15 shows that while the superheat is being controlled as above the boiler efficiency has varied less than two per cent, in spite of the rather radical change in the distribution of the gases through the two sides of the boiler. The fact that the change in efficiency is no greater is because the boiler in question has a rather flat efficiency-rating curve so that appreciable changes in gas flow between the two sides, which corresponds to changing the rating in them, has a relatively minor effect upon the efficiency.

SEPARATELY FIRED SUPERHEATERS.

Unquestionably the ideal way of controlling superheat is by means of separately fired superheaters. It may not always be the most feasible way from a commercial, space, or weight point of view, but as a means of controlling superheat no other method has ever equalled it.

The simplest type of separately fired superheater is one made only of tubes containing the steam to be superheated, the furnace being made large enough so that there will be no danger of local flame impingement with consequent hazard of losing tubes due to such impingement. It is quite customary in stationary installations of this type to have the gases from the furnace pass through a checker-work of firebrick before reaching the superheater tubes, to insure entire absence of local overheating due to flame impingement on any portion of these tubes. In marine practice it is difficult, because of space and weight limitations, to utilize a furnace of the size necessary for a "dry" type of separately fired superheater, and accordingly the designs which have met with approval for installations afloat incorporate protection to the superheater in the form of a water screen. Such a screen serves not only to protect the superheater unit from the hazard of local overheating, but also to generate a substantial percentage of the steam used by the propulsion machinery.

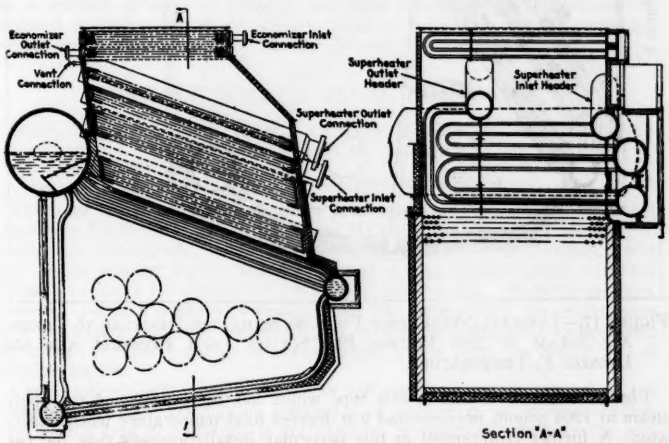


FIGURE 16.—SEPARATELY FIRED SUPERHEATER DESIGNED TO SUPERHEAT 500,000 POUNDS OF STEAM 200 DEGREES F. AT 400 POUNDS PER SQUARE INCH PRESSURE.

Figure 16 illustrates a marine type of separately fired superheater designed to superheat approximately 500,000 pounds of steam per hour to 200 degrees F. superheat at 400 pounds pressure, the water screen under these conditions generating 65,000 pounds of steam per hour. When maneuvering a ship with such a unit, the fuel input may be reduced to give any desired superheat, the saturated boilers taking care of the power requirements. When coming in or out of port, the separately fired superheaters may be secured, the steam from the saturated boilers being ideal to meet these requirements. While the ship is in port, only saturated boilers need be on the line.

The primary disadvantage of the separately fired superheater for marine use is the fact that relatively large powers with a multiplicity of boiler units are desirable for its satisfactory application. This is because a relatively compact separately fired superheater unit will handle a large quantity of steam to be superheated, introducing an extra unit in the fireroom of a low-powered ship, which it is hard to justify from a commercial point of view. To meet this situation the integral separately fired superheater was developed to provide all the advantages of separately fired superheaters, without increasing the number of units in the boiler room of a ship of moderate horsepower.

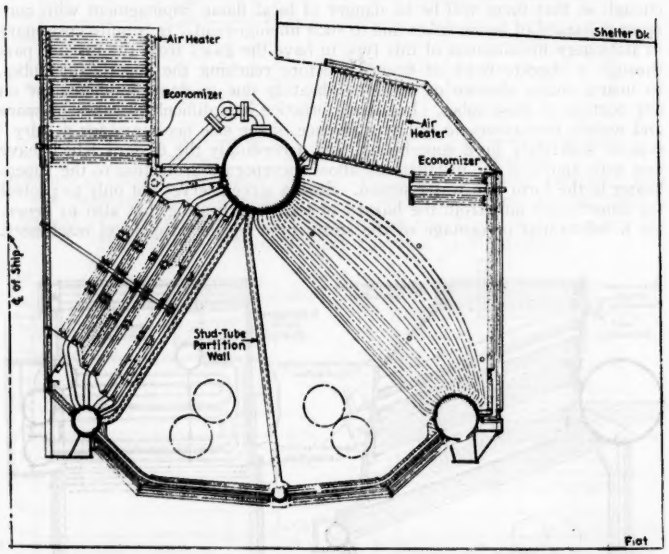


FIGURE 17.—INTEGRAL SEPARATELY FIRED SUPERHEATER DESIGNED TO GENERATE STEAM AT 1200 POUNDS PER SQUARE INCH PRESSURE AND 950 DEGREES F. TEMPERATURE.

Figure 17 shows a unit of this type which has been developed to supply steam at 1200 pounds pressure and 950 degrees total temperature when underway. A further requirement in this particular installation was that 100 per cent of full ahead steam be provided for maneuvering purposes at a temperature not to exceed 750 degrees F. Although the designed steam pressure and temperature of the unit shown in Figure 17 are unusually high for present

marine practice, it is referred to purposely to emphasize the flexibility and convenient operating characteristics of this type of superheat control in meeting extreme seagoing conditions. The application of this principle of control is equally appropriate for the more moderate steam pressures and temperatures in common use in modern ships at the present time.

For the unit shown in Figure 17 automatic combustion control is provided which assures any desired steam pressure and temperature over the entire range of boiler rating. Wide range oil burners having no return flow of oil are used. The burners and their air supply on the saturated side of the boiler are controlled by the steam pressure in the boiler drum, the burners and the air supply to them under the superheater side of the boiler being controlled by the temperature of the steam at the superheater outlet.

The gas-tight water-cooled wall separating the saturated and superheater sides of the furnace is of the Babcock & Wilcox Company stud-tube design having refractory surfaces exposed to the furnace which assist in maintaining the combustion efficiency in the small furnaces available in marine work and also reduce the heat absorption per square foot of wall, so that there is little danger of local overheating of the wall tubes even in the burner zone.

A boiler unit of this type may be operated in port with the burners lighted under the saturated side only, or, if a moderate superheat is desired for the auxiliary generators, this may be obtained by the use of one burner under the superheater, the remainder of the auxiliary load being taken directly from the steam drum without the necessity of desuperheaters. The efficiency characteristics of such a unit parallel those of a boiler fitted with damper control. Such a design of boiler is inherently slightly heavier than the more orthodox A-type boiler fitted with damper control, but the practical advantages, from an operating point of view, possessed by such a unit counteract the weight differential involved.

Control of superheat is an accepted necessity in the modern steamship. Applying the most feasible control from a practical operating and efficiency point of view is the problem facing the naval architect and owner. There are a number of ways of doing it, and each installation must be carefully analyzed to insure that the procedure followed is the best for the particular service under consideration.—" Marine Journal," 15 December, 1935.

SOME FACTORS IN NAVAL LIMITATION.

Capital Ships at Next Week's Conference—Effects of Advance in Gun, Torpedo and Mine Design.

(From Our Naval Correspondent.)

The trend of armament design in the past ten years is a factor in the Naval Limitation Conference, which the Prime Minister will open next Monday, to which, not unnaturally, public opinion has been very little directed. Not only is the subject highly technical, but it is also hedged about with the (quite necessary) restrictions of the Official Secrets Act. Professional men, however, are in a position to realize from the merest hints the implications of many things that have happened, and to them the decisions to be made, particularly on the question of capital ships, in the next few weeks are of peculiar interest.

Conversations with naval men of the different powers represented at the Conference show a remarkable unanimity of opinion on at least one point. The *Nelson* type of battleship is not likely to be repeated, whatever the outcome of the Conference.

Even though the limit of 35,000 tons be retained and all the powers build only to that displacement, technical progress since the *Nelson* and *Rodney*

were designed has been such that the design no longer meets the requirements. It is claimed that, for the moment the offensive element in naval warfare is ahead of the defensive measures as embodied in existing ships, and that in any new 35,000-ton design the defensive will have to be increased.

The need for this is placed to the credit of advances in guns, in torpedoes and in mines primarily; but it must not be overlooked that anti-aircraft measures also enter far more into the problem than they did ten years ago. Foreign naval officers in particular are very much impressed by the improvements in gunnery that have been made by armament designers, even during a period when the demand for big guns was practically stagnant. Every Admiralty, too, has encouraged the development of mining during the past decade, and while it is well known that development of the torpedo in the direction of increased size has not yet been wholly successful, improvements in the 21-inch type have been such that it has become a much more formidable weapon, even against the modern, subdivided, bulged capital ship than it was when used under conditions of actual warfare.

The limitation of displacement, therefore, presents to the naval architect a problem in compromise. True, the *Nelson* design was only 33,500 tons, so that he has an extra 1500 tons at his disposal, but even so, considerable savings in weight must be made somewhere if he is to incorporate in the new design all the defensive improvements that the naval officers are demanding.

We shall probably find this factor affecting the discussions at the Conference on the maximum size of gun to be mounted in any new capital ships. The limitation agreed to at Washington was 16-inch caliber. Nine 16-inch guns with their mountings absorb considerable weight, added to which there is the controversy about the efficiency of triple turrets. There appears to be sufficient expert support for a reduction of the limit to eight guns of 14-inch caliber. The idea has undoubtedly been considered at the private conversations which have taken place during the past twelve months.

This would be a revolutionary change in British naval ordnance. We progressed. it will be remembered, from the 13.5-inch gun in the *Iron Duke* class to the 15-inch in the *Queen Elizabeth,* and the only 14-inch pieces ever used by us were mounted in the *Canada* (ex *Almirante Latorre*), designed for the Chilian Navy and taken over by us at the outbreak of the war. The difference in caliber caused a certain amount of difficulty with ammunition supply at first, but that was overcome.

Would the adoption of the 14-inch gun be a retrograde step?

Gunnery specialists with whom the question has been discussed are of the opinion that it would not. Gun design has made such strides that they hold that the smaller caliber today will provide all the hitting power likely to be required and that, in any case, 14-inch guns on a platform that is still afloat are more useful than 16-inch guns that have gone to the bottom of the sea.

Another point in the naval discussions about which opinion has been hitherto uninformed—or, more exactly, misinformed—is the duration of any new limitation that the powers may impose on themselves by the negotiations.

It has come to be generally accepted that the period would be six years. There is good reason to believe that it is more likely to be 10 years.

This, on reflection, will be seen to be a more reasonable period than that first suggested. It is quite certain that not all the 700 replacement ships for the five fleets affected by any new limitation will be put into service between 1937 and 1942. Indeed, many of them may not be laid down until the later year. Even in 10 years' time none of them will have reached the age limit so as to call for further replacement. The assembling of another conference before there is any probability of big new building programs being under consideration would be unnecessary, if not indeed, unwise—"Shipbuilding and Shipping Record," 5 December, 1935.

ASSOCIATION NOTES.

ELECTION OF OFFICERS.

The following have been elected as officers of the Society for 1936:

President:

Admiral Wm. H. Standley, U. S. Navy.

Secretary-Treasurer:

Commander C. S. Gillette, U. S. Navy.

Members of Council:

Captain Albert Norris, U. S. Navy.
Commander Penn Carroll, U. S. Navy.
Commander Lybrand P. Smith, U. S. Navy.
Commander H. E. Saunders (CC), U. S. Navy.
Commander G. R. O'Connor, U. S. Coast Guard.
Mr. H. B. Gregory.
Mr. Roland Whitehurst.

ANNUAL BANQUET.

The Annual Banquet of the Society will be held on Friday, April 3, 1936, at the Willard Hotel, Washington, D. C. Indications point to an event comparable with the most successful of these occasions. The Committee in charge consists of Captain C. A. Jones, U. S. Navy; Commander R. W. Paine, U. S. Navy; Commander C. S. Gillette, U. S. Navy; Lieut. Commander W. M. Thompson, U. S. Navy; Lieutenant T. A. Solberg, U. S. Navy; Lieut. Commander L. F. Small, U. S. Navy; Mr. P. N. Israel, Mr. A. F. E. Horn, and Mr. Roland Whitehurst.

MEMBERSHIP.

The following have joined the Society since the publication of the last previous JOURNAL:

NAVAL.

Anderson, William L., Lieutenant, U. S. Navy.

Larson, Lester M., Chief Electrician, U. S. Navy.

Mills, A. P., Lieut., U. S. N. R., 216 Pomona Ave., Long Beach, Calif.

Palmer, Charles J., Lieutenant, U. S. N.

CIVIL.

Jackson, P. B., Aluminum Corporation of America, 2210 Harvard Ave., Cleveland, Ohio.

Letsinger, Paris E., Vice President, Cummins Engine Company, Columbus, Indiana.

ASSOCIATE.

Attendu, A. C., Professor of Aviation & Diesel Engines, Montreal Technical School, Montreal, Canada.

Taylor, S. J., 2951 Pine St., San Francisco, Calif.